1974

A study of engineering services for South Dakota hospitals

Duane Robert Nelson

A STUDY OF ENGINEERING SERVICES FOR SOUTH DAKOTA HOSPITALS

BY

DUANE ROBERT NELSON

A thesis submitted
in partial fulfillment of the requirements for the
degree of Master of Science, Major in
Electrical Engineering, South Dakota
State University

1974

A STUDY OF ENGINEERING SERVICES FOR SOUTH DAKOTA HOSPITALS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Electrical Engineering Department Date

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. Duane E. Sander for his advice, assistance, and guidance throughout the course of this project.

D.R.N.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Engineering Services in the Hospital

Medical instruments, or biomedical electronic instruments, as they are sometimes referred to, are playing an ever-increasing role in aiding the physician and nursing staff of every hospital in the United States and abroad. Biomedical electronic equipment provides life-saving and life-monitoring functions as well as aiding hospital personnel in clinical, diagnostic, and therapeutic areas. Although electronics dates back about 50 years into the medical field, the quality and quantity of recent engineering developments for the health care field has tended to obscure earlier developments. Some of the electronic devices used presently were not even considered in the mid 1950's.[1] "Hospitals have become environments of major complexity in the past ten years."[2] "The use of diagnostic and therapeutic devices has increased dramatically."[3] "Most functions of the human body can be analyzed by means of, or with the aid of electrical or electronic devices."[1] An average 200-bed hospital can easily have over 400 medical instruments utilizing electronic circuitry.[4] Each day more complex, sophisticated, and technologically challenging instruments are being developed to meet the expanding needs of the health care field.[3] The well-known

shortage of physicians has put an increased demand on automated equipment, diagnostic instruments, and other instrumentation to help the physician perform with greater efficiency and much less effort.

Success of the medical enterprise depends upon the attention and dedication of engineers. The administration of adequate health care is not a question of physicians having enough time, or of having enough physicians, for without engineers the physician does not have all the skills. "Doctors need all the engineering help they can get."[5]

Engineering services can provide the physician and the hospital with the engineering skills they need. These needed engineering skills are those of the bioengineer, biomedical engineer, or biomedical electronic technician. Engineering services are needed to: assist hospital personnel in the proper and safe operation of biomedical equipment; maintain equipment on both a preventative and corrective maintenance basis; provide a safe electrical environment for the hospital staff, patients and employees; assist administrators in interpreting technical specifications of complex biomedical instruments under consideration for purchase; serve as a consultant for plant remodeling and expansion; and provide a liaison between manufacturer and hospital.

Hospitals are requiring an increasing amount of engineering services. Not all of these needs are being met.

"The nature and level of engineering support available to the staff of the average hospital is far from optimum."[6] "Few hospitals have graduate engineers or skilled biomedical electronic technicians; most still depend on the electrician or maintenance man to handle their necessary electrical safety and testing program. Many of these men have little formal electronics background."[7] "Physicians must rely on manufacturers' statements and claims of safety and effectiveness. Physicians and consumers have no way of knowing the hazards and potential dangers of some of the devices they use."[3] A growing concern and awareness of the relationship between equipment safety and maintenance has been reflected in recent changes in the "Manual for Hospitals" published by the Joint Commission on Accreditation of Hospitals which draws attention to the importance of adequate equipment maintenance and competent engineering guidance. This growing concern and awareness is also evident in the "Accreditation Manual for Hospitals", published by the American Hospital Association. Here are some direct quotes from the "Accreditation Manual for Hospitals" as quoted in a pamphlet from a hospital safety testing laboratory:[8]

> Page 59...."The condition of the operating room electrical equipment, such as cords, plugs, switches and various electronic devices, shall be inspected regularly; the conductivity of equipment should be tested by a competent engineer. A written record of the results of these inspections should be kept."

> Page 84...."Electrical Safety. All personnel must be made aware of the fact that the use of electricity introduces the hazards of burn, fire, electric shock and power failure. Special precautions must be taken when the care of patients requires the use of any type of electrically operated devices. All appliances, instruments, and installations shall be tested to determine compliance with current leakage, proper grounding and other device-safety requirements to ensure protection of patients and employees. There shall be strict prohibition of extension and indiscriminate overloading of electrical systems. Expert advice concerning electrical systems shall readily be available at all times."
>
> Page 147...."There shall be a written preventive maintenance program that includes techniques for cleaning and for contamination control, as well as for the periodic testing of all equipment."
>
> "When electronic devices are used on patients, especially patients who have intravenous catheters or wires leading to the heart, special safety precautions, related to proper grounding, current leakage and device-safety must be observed. Potential electrical hazards should be recognized in the event that electrically operated beds are used. Expert advice concerning the safe use of, and preventive maintenance for, all biomedical devices and electrical installations shall be readily available at all times. Documentation of safety testing should be provided on a regular basis to the unit director."

Definite codes and specifications for hospitals are also defined in pertinent sections of the National Electrical Code (NEC)[9], Occupational Safety and Health Act (OSHA)[10], and National Fire Prevention Association (NFPA)[11]. Compliance with these requirements is not easily made through normal administrative actions. These requirements increase the needs for engineering services for the hospital.

The medical and nursing staff do not receive adequate

training in operation or use of new instruments and devices. Medical and administrative staff responsible for selecting and purchasing new instruments struggle with the technical specifications and details, not always making a rational decision. In addition to these problems, new instruments and devices seem to be out of service often, and for long periods.[6] Engineering services can alleviate many of these problems. The hospital bioengineer can interpret electrical codes and technical specifications, train medical and nursing staff in the proper use and operation of new devices, and provide preventative and corrective maintenance programs to allow instruments and hospital facilities to better serve the patient and staff. The bioengineer is a source of professional advice and consultation, and can provide the modern hospital with the engineering services it needs for safe and economical use of medical instrumentation.

Health care delivery problems are being tackled continually across the nation by doctors, specialists, scientists, bioengineers and biomedical engineers. This industry is receiving more attention daily as man strives for better health and improved health care. Yet, this industry requires special management to solve its variety of problems in many numerous environments. Bugliarello[12] identifies the problem by stating, "The health care industry differs from other large industry in that it has problems which are national in

scope, yet must be solved on a 'regional' basis."

1.2 The Need for Engineering Services in South Dakota Hospitals

The hospitals in South Dakota, like all other hospitals, need engineering services for efficient and economical operation. Presently, about one-half of the hospitals licensed by the State Health Department are accredited by the Joint Commission on Hospital Accreditation. Mr. Morton, Administrator at Yankton's Sacred Heart Hospital, indicated that about one-half of South Dakota's hospitals are meeting the required standards, for hospital safety and equipment maintenance, of the Joint Commission on Accreditation of Hospitals. The larger hospitals in the state have personnel providing engineering services, but these larger hospitals comprise a small part of the total health care facilities in the state. This thesis is concerned with the smaller hospitals in South Dakota that cannot afford full-time services of this type. Before the subject can be presented, some data pertinent to South Dakota will be discussed.

Located in the upper midwest, South Dakota is a "land of infinite variety", consisting of hills, rolling plains, farmland, and rural communities, with a total population of 672,000. Of the 67 counties, two counties with populations of 86,600 and 58,200 characterize the two semi-metropolitan areas located at opposite ends of the state.[13] Seven other main trade centers are dispersed mainly in the eastern half

of South Dakota, and range from 12,700 to 34,100 population.[14] (See Figure 1.) The majority of trade centers are located east of the Missouri River, where approximately 489,000 of South Dakota's 672,000 people live. South Dakota's population is served by 72 hospitals providing 4,992 beds. Of these 72 hospitals, 62 are licensed by the state Health Department and are non-federally supported, providing 3,676 beds. (See Figures 2 and 3.) Hospital sizes range from 14 beds to 357 beds. (See Appendix A.) Ten federally supported hospitals exist in South Dakota providing 1,296 beds.[15] Seventeen of the 62 state licensed hospitals are west of the Missouri River; the remaining 45 are east of the Missouri River. (See Figure 3.) Occupancy rates of these hospitals range from 20% to 87% with the average occupancy being 58%. The average state licensed hospital capacity throughout the state is 59.3 beds per hospital. (See Figure 4.) The average total hospital capacity in South Dakota is 70.0 beds per hospital. In comparison, the average hospital capacity in the United States is 133 beds per hospital.[15,17] (See Table I.) The United States Public Health Service defines five county group classifications as follows:

Group 1: Greater Metropolitan--counties with one million or more inhabitants.

Group 2: Lesser Metropolitan--counties with 50,000 to one million inhabitants.

Group 3: Adjacent--counties contiguous to metropolitan areas. Population in such counties range from 500 to 508,500 inhabitants.

FIGURE 1

SOUTH DAKOTA POPULATION IN THOUSANDS AND COUNTY GROUP CLASSIFICATIONS DEFINED BY THE UNITED STATES PUBLIC HEALTH SERVICE

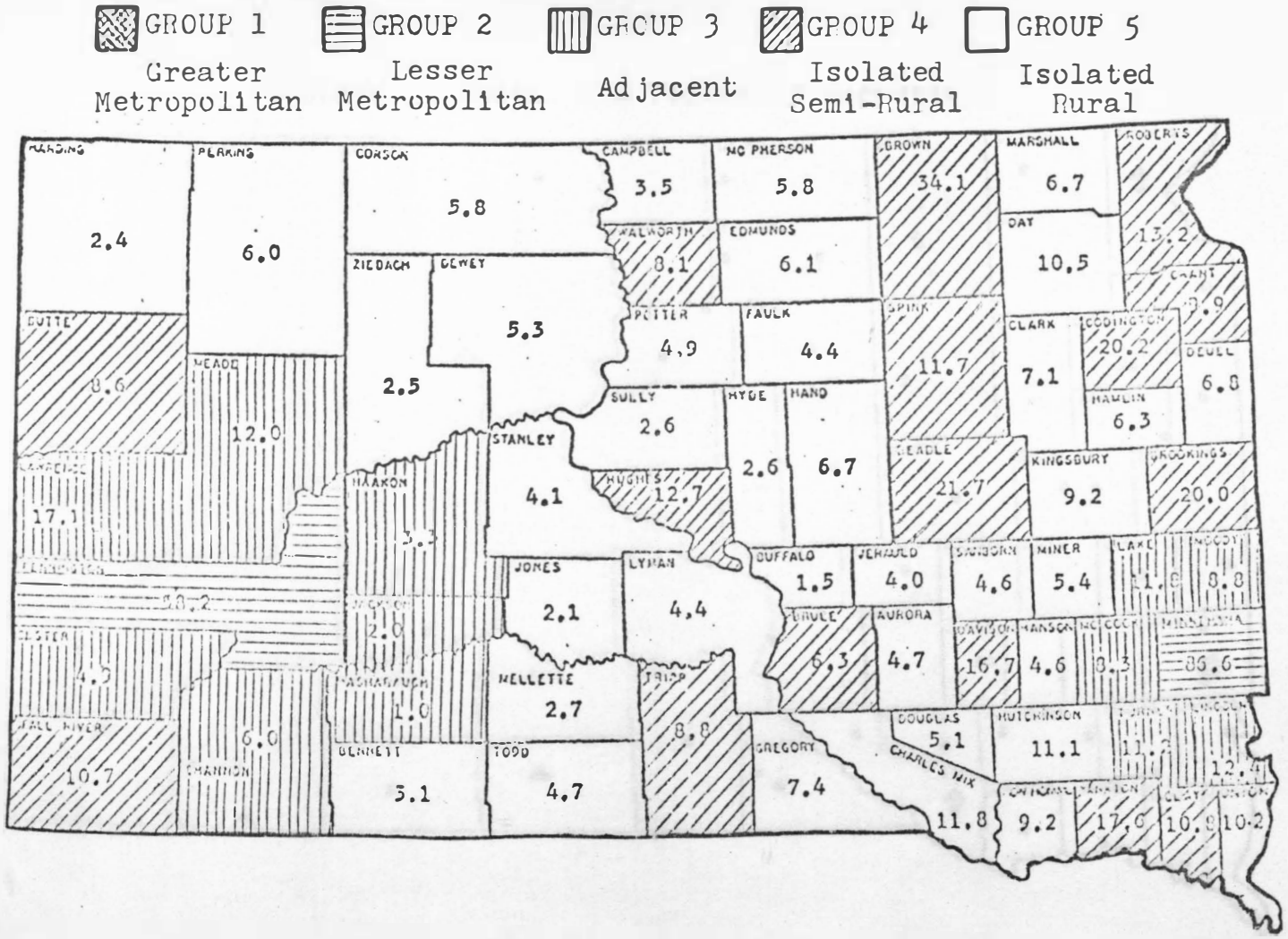


FIGURE 2

DISTRIBUTION OF HOSPITALS IN SOUTH DAKOTA

• State Licensed ▲ Federally supported

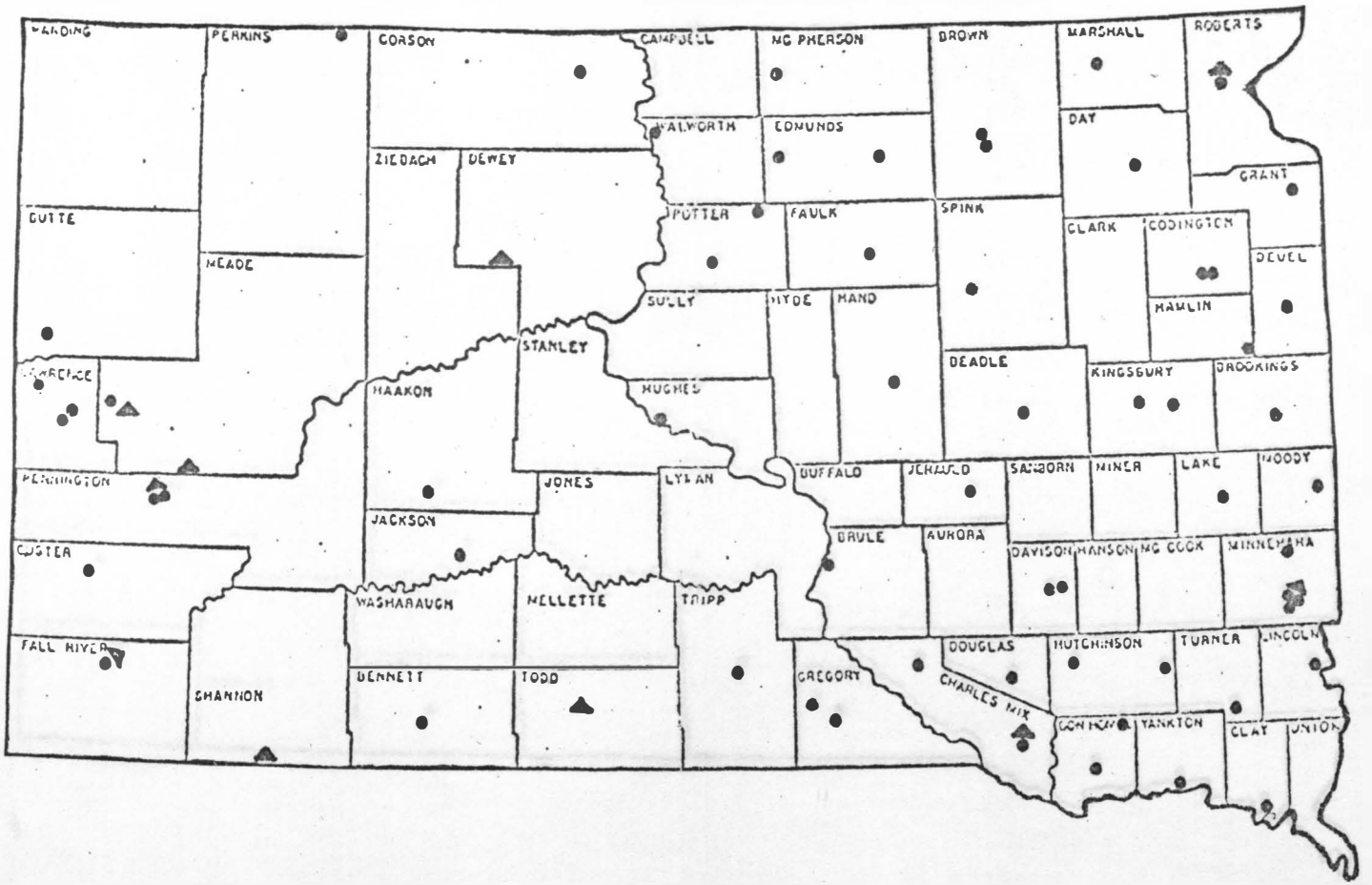


FIGURE 3

DISTRIBUTION OF SOUTH DAKOTA HOSPITALS LICENSED BY THE STATE DEPARTMENT OF HEALTH (NON-FEDERAL)

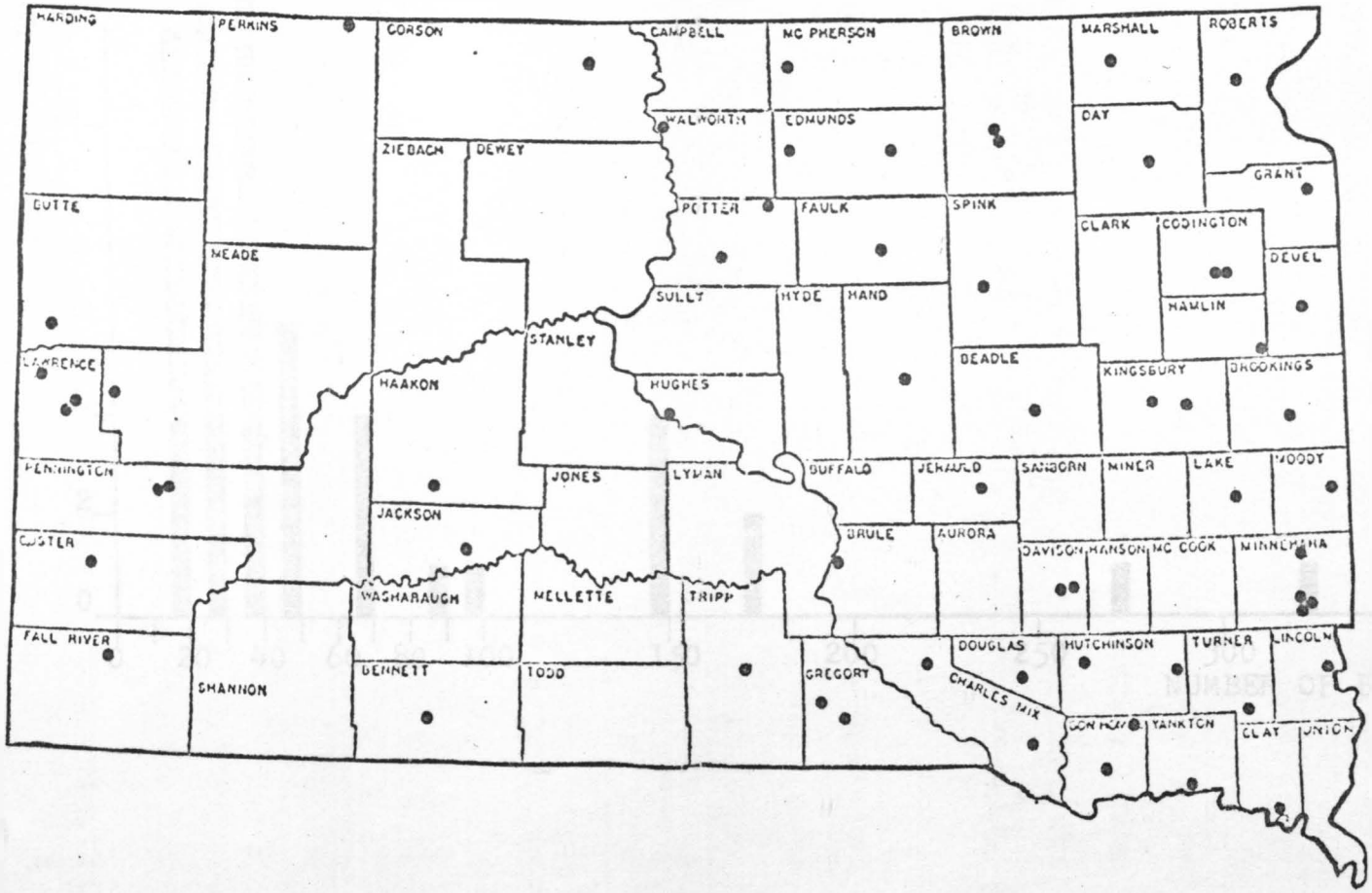
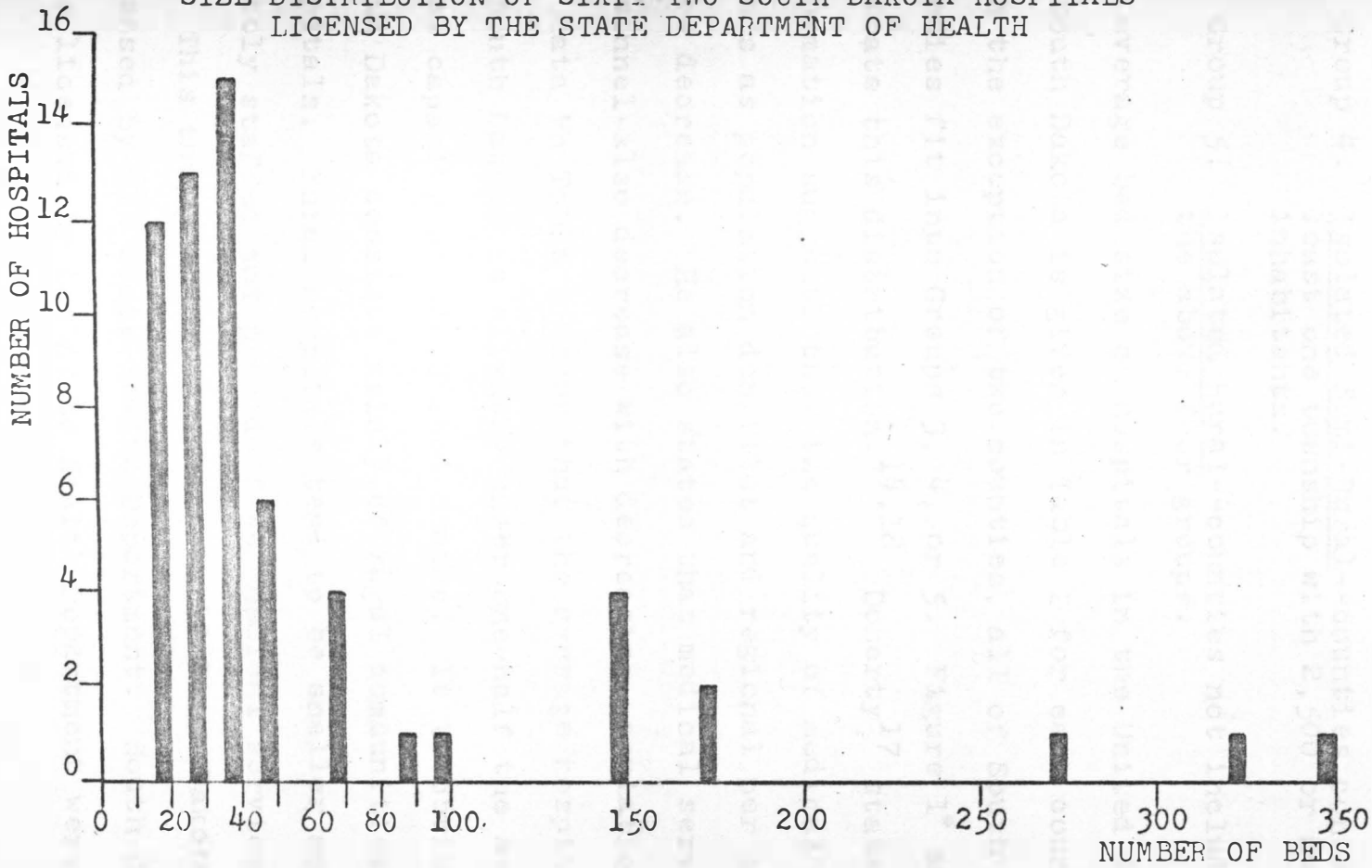


FIGURE 4

SIZE DISTRIBUTION OF SIXTY-TWO SOUTH DAKOTA HOSPITALS LICENSED BY THE STATE DEPARTMENT OF HEALTH



Group 4: Isolated Semi-Rural--counties containing at least one township with 2,500 or more inhabitants.

Group 5: Isolated Rural--counties not included in the above four groups.

The average bed size of hospitals in the United States and in South Dakota is given in Table I for each county group.[17] With the exception of two counties, all of South Dakota's 67 counties fit into Groups 3, 4, or 5. Figure 1* and Table I indicate this distribution.[14,18] Doherty[17] states that this information suggests that the quality of medical care declines as population densities and regional per capita incomes decrease. He also states that medical services and personnel also decrease with decreasing population densities. The data in Table I shows that the average hospital capacity in South Dakota is slightly under one-half the average hospital capacity of the United States! It is obvious that South Dakota consists mainly of rural communities with rural hospitals. Rural hospitals tend to be smaller and less adequately staffed and provide fewer medical services.[17]

This thesis will address those 62 South Dakota hospitals licensed by the State Health Department. South Dakota hospitals licensed by the State Health Department were selected

---

*Portions of Figures 1, 2 and 3 are reproduced with permission of Lee Opheim, from Atlas of South Dakota, Dubuque: Kendall/Hunt Publishing Co., 1970, pp. 105, 131.

TABLE I

AVERAGE SIZE AND NUMBER OF UNITED STATES AND SOUTH DAKOTA HOSPITALS BY COUNTY GROUP CLASSIFICATION

ITEM	COUNTY GROUP				
	1	2	3	4	5
United States Average Number of Beds Per Hospital	227	197	81	78	33
Distribution of 67 South Dakota Counties by County Group	0	2	12	16	37
Distribution of 10 Federally Supported Hospitals in South Dakota	0	2	3	2	3
Distribution of 62 South Dakota Hospitals Licensed by the State Department of Health	0	6	11	19	26
Average Number of Beds per Federally Supported South Dakota Hospital by County Group	0	206	176	134	37
Average Number of Beds per State Licensed South Dakota Hospital by County Group	0	154	35	85	26

as being most in need of engineering services and being subject to similar budgets and cost constraints.

As indicated by Bugliarello,[12] problems of the health care industry must be solved on a "regional" basis. The South Dakota "region" was described in the earlier part of this section. Although South Dakota has nine hospitals of more than 100 beds, the majority of the remaining 53 are in semi-rural or isolated rural areas. Their capabilities in the delivery of health care are limited because of their size, the average hospital capacity being 59.3 beds, a figure far below the national average. (See Table I.) Johns[19] states that a major factor limiting the impact of engineering science and technology on hospitals is the lack of economic resources. The hospitals do not have the necessary financial support for specialized engineering services dealing with biomedical equipment and its associated areas of importance in their hospital; namely, electrical safety, preventative and corrective maintenance, and basic plant engineering.

This situation is extremely evident in South Dakota. Due to their small size, many hospitals can only maintain the minimum of biomedical equipment. When an instrument fails to operate or malfunctions, it has to be sent in to the manufacturer or repaired by the manufacturer's service representative at a service center or at the hospital. Although these two alternatives both solve the malfunction, they are quite costly and time consuming. During repair, the hospital

is usually without the use of that instrument. However, in some cases where the instrument is of significant importance to proper life functions, a loaner instrument is provided by the servicing agency until the hospital's instrument is repaired. When a manufacturer has to send out a service representative, charges commonly include mileage, expenses, materials, and labor. Labor charges range from $15.00 to $25.00 per hour, and "time on-the-job" usually starts when the representative leaves his office, not when he arrives on the job. Problems encountered in sending malfunctioning equipment to the manufacturer for repair are; damage in shipping, extra delays in use of the instrument, and unpredictable events such as loss or accidents.

These are not the only alternatives for the South Dakota hospital. The author visited with Mr. Brown, a representative of Kreiser Surgical, Inc., Sioux Falls, South Dakota, and found that the hospital supply house will service biomedical equipment, but usually only the name brand that they distribute. Their services are mainly general maintenance, and seldom consist of technical electronic troubleshooting. This service is performed in their office, obtaining faulty equipment from hospitals via bus transportation, as opposed to the larger expense of sending a serviceman out to the hospital. If the hospital's particular piece of equipment is "one-of-a-kind" or of extreme importance, this hospital

supply company will furnish a "loaner" instrument while the original is being repaired. In some areas electronic technicians, TV repairmen, or electrical engineers are available for possible service work, but instances are too few to be an adequate source of equipment maintenance. In addition, such personnel are many times unfamiliar and basically unqualified to perform proper maintenance in a safe and reliable fashion.

Although South Dakota is not unique, there are additional reasons why it has its share of safety and maintenance problems. Most of the hospital facilities in the state were built prior to the mid-1950's. Most hospitals built at this time or earlier were not designed to accommodate the electronic devices now in use in the hospital.[1] As a result, many undesirable features are evident in these hospitals, such as lack of proper space or facilities for equipment, makeshift arrangements for wiring and grounding which are not in compliance with standards, and the general use of old equipment made 10 to 30 years ago. Of course, all hospitals would prefer new equipment, but financial resources are lacking. A high turnover of hospital personnel is also evident. Although the hospitals of South Dakota need a variety of engineering services, the present lack of trained biomedical electronic technicians, the continual shortage of financial resources among hospitals, and the irregular distribution of small hospitals throughout the state has prevented the establishment of these services.

1.3 Purpose and Scope of Thesis

This thesis is written with the intent of surveying South Dakota hospitals to determine their present engineering services needs and then suggesting an engineering services program for the improvement and optimization of health care delivery in the state. A variety of programs with these general intentions will be presented in the literature review, and basic features will be discussed. In addition to specific programs, some manufacturer's policies and testing laboratory services will be presented. The hospital survey will be discussed and the results will be evaluated. Feasible programs for engineering services will be presented and suggested.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

2.1 Introduction to Engineering Services

Many recent efforts have been made to provide engineering services to the hospital environment. Sometimes termed "shared" engineering services, these programs have similar goals in mind, but differ greatly in services provided, financial structure, and the delivery of these services. Kane[20] refers to these services as follows: "There are two basic plans in use today. One is the concept of a central stable of technicians and the other is that of individual technicians placed in the various hospitals involved in the plan."[20]

2.2 Engineering Service Programs in the United States

Engineering services are now a reality for some medical centers and hospitals throughout the United States. These plans have recently been initiated, some of them being no more than one year old. Seven engineering service plans will be presented in this Section. The various programs referred to as "shared" engineering services will be described.

2.2.1 Massachusetts Medical Engineering Program

A "Pilot Study for a Medical Engineering Shared Service", presented by S. Aronow and P. Zambuto[21] was initiated to determine the need for, and format of, a shared service in

medical engineering and electrical safety and also initiate such a program in Massachusetts. A survey was taken to determine the nature of electrical safety problems and the magnitude of manpower requirements.

Fifteen hospitals were surveyed throughout the state of Massachusetts. A group of three hospitals were selected as a model for regionalization studies. Under the regional plan, a group of small hospitals in close proximity to a larger one arrange direct sharing of personnel between them. The survey consisted of an inspection visit by a team of engineers which examined all patient areas and special facilities of the hospitals surveyed. Safety checks were also made, including current leakage and proper grounding of equipment, polarity and tension of receptacles, grounding of exposed metal in patient vicinities, and proper operation of isolated power systems.

End results of the survey indicated that hospitals were quite varied in their capabilities to handle these problems, and each hospital appeared to be susceptible to both unique and general problems in electrical safety and equipment maintenance. Of the statistical information gathered concerning bed size, staff size, use of facilities, etc., no trends could be discerned. This emphasized that all hospitals are not alike, and therefore a stereotyped program for all hospitals would not necessarily appeal to every hospital. Of

particular note was that some 100 bed hospitals had more full-time personnel involved with electrical safety and equipment maintenance than some 300 bed hospitals. However, the smaller rural hospitals generally had no personnel dedicated to medical engineering tasks. Many of the hospitals surveyed were concentrating their efforts on monitors, but none were conducting preventative maintenance on the entire range of biomedical equipment. Specific conclusions of this study were:

1. "Sufficient need exists in the state of Massachusetts to justify a shared service in medical engineering."

2. "This service should offer the hospitals safety inspection packages, equipment maintenance, and repair construction and modification service, engineering consultation and education."

3. "The most immediate needs are in inspection, consultation, education, and preventative maintenance. Repair and construction service will be phased in at a later date."

4. "The manpower which appears to be required for a hospital to conform to currently recognized practice is one full-time equivalent person per 200 beds."

The Medical Engineering Program, (MEP), a shared service, was set up based on these conclusions. In its first year, October 1, 1973, to September 30, 1974, the project is expected to grow to four full-time people and a budget of $90,000. On-call repair services will be added in early 1974. Complete services in maintenance and repair are offered to all hospitals but are expected to be used fully by

only the small hospitals having little in-house staff. Consultation services and educational programs will be utilized by all hospitals. MEP will be self-supporting early in the second year of operation and, as of October 3, 1973, eight hospitals have initiated participation in the program. The Massachusetts study concludes that the Medical Engineering Program as a shared service will provide Massachusetts hospitals with a comprehensive program in medical engineering and electrical safety which can be utilized by any hospital to the extent needed.[21]

2.2.2 A Biomedical Engineering Shared Service in Southern California

Launched February 1, 1974 with a $676,000.00 W. K. Kellogg Foundation Grant to underwrite initial costs of program development, the Hospital Council of Southern California proposes a broad-scale multidimensional response to optimize the nature and level of support available to the average hospital staff. This service will operate under a full-time director. During the first three years of the program, an engineering center and five satellite laboratories will be established. This shared service program will involve more than 70 hospitals, three universities, the Biomedical Engineering Institute of the University of Southern California, the Jet Propulsion laboratories, and several government agencies. It will include, "training programs, government and manufacturer liaison, preventative

maintenance and quality control programs, 24-hour emergency repair, aid in purchase planning, single-time safety checks, equipment installation, and aid in documentation procedures." The Engineering Center will direct management, administrative, and fiscal affairs, establish a standards and calibration laboratory, and maintain a mobile testing van and portable calibration equipment. Five satellite service laboratories will be set up throughout six counties in the first three years. "Each satellite will contract from eight to twelve hospitals for maintenance and repair services." Supervised by an "area" engineer, each satellite laboratory will be distributed so that no contracting hospital is more than 20 minutes away from the service center. Each satellite service center will have four to seven technicians, who will also help administer training programs to hospital staff in addition to their normal maintenance function. Eberhard and Ridgeway[6] state:

> Nothing can serve as a replacement for engineering staff working in the day-to-day context of the hospital.
>
> We expect our staffing patterns (days per week in the hospital) to vary with the needs of the individual hospitals. Some small hospitals may need a technician with appropriate back-up only three days a week, while other hospitals may want two BMET's on a full-time basis.

This program will receive significant assistance from the vast amount of biomedical resources in the Southern California area. Within Los Angeles County, there are more

than 300 medical equipment manufacturers, four universities offering 2-year, 4-year, and advanced degrees in biomedical engineering, and University of Southern California Biomedical Engineering Institute.

A recent issue of Hospital Forum[6] stated advantageous characteristics of California's shared service approach as being comprehensiveness, efficiency, convenience and flexibility. The service is comprehensive because it provides the normal and specialized services that a small organization cannot. Relying on the sharing approach, the service is efficient, and provides only the exact amount of services needed in one-man increments. Lastly, a convenient and flexible service can keep up with changing needs and provide the variations of professional assistance required. This Hospital Council of Southern California Program is a creative effort by hospitals to improve health care delivery in a cost effective manner.

The author should point out that no information was obtained on the program's financing after the initial three year period, but general indications are that it will be self-supporting, receiving its financial resources from the hospitals involved.

2.2.3 The Carolinas Hospital Engineering Support Services

"The Carolinas Hospital Engineering Support Services (CHESS) is a Division of Carolinas Hospital and Health Services, Inc. (a non-profit shared service corporation

established by the South Carolina Hospital Association and the North Carolina Hospital Association)."[2] CHESS provides two specific services, either or both to which the hospital may subscribe. Hospital plant engineering services will consist of: plant engineering surveys, consultation on minor construction projects, training programs for plant maintenance personnel, interpretation of NEC, OSHA, NFPA, and other building codes, assistance in acceptance of contractor projects and in troubleshooting complex hospital plant maintenance programs, and the scheduling and evaluation of preventative maintenance programs for building service equipment. These services are based upon a minimum of 24 man-days each year per subscribing hospital. The biomedical instrumentation services of CHESS are provided to enable the hospital to deliver "state of the art" health care economically and safely. The biomedical instrumentation service is based upon a minimum of 24 man-days each year per subscribing hospital, and includes: evaluation of instrumentation needs, assistance in planning equipment purchases and installation, complete inventory information and annual replacement schedules, equipment hazard and safety program, performance of preventative maintenance for selected critical medical instrumentation, hospital staff training in instrument application, safety and user maintenance, development of written instrumentation procedures to meet regulatory and accreditation standards, and

calibration and certification of life saving, life supporting, and life sustaining instrumentation.[2]

A survey taken of North and South Carolina hospitals indicated an immediate acceptance and desire to participate by 80% of the licensed facilities.[22]

Subscribing to CHESS enables hospitals to receive professional services without adding additional staff. All service fees are determined by a Board of Trustees, representing the subscribing hospitals' interests. Initial grant financing was provided by the Duke Endowment and the W. K. Kellogg Foundation and will be applied over a three year start-up period. Initial subscribers will benefit from lower costs during the end of the third year. Annual costs are expected to stabilize at $7,300.00 per subscriber for both services. The cost for hospital plant engineering services will be $4,000.00 per year and the basic biomedical instrumentation service will be $3,300.00 per year. Additional instrumentation service will be available at $15.00 per hour for subscribers.

CHESS was operational June, 1973, and plans to increase its services as it grows. Within the first three years five or six service centers will be set up, located as centrally as possible in the geographic area they support.[2] In correspondence with CHESS on March 14, 1974, the author was informed that 24 hospitals were now under contract with CHESS.

2.2.4 The Nyack Shared Engineering Plan

The Nyack Plan, sometimes referred to as the "Kingpin" concept, is a true shared Biomedical Instrumentation Engineering Plan that involves the establishment of a position in a central contractor hospital (Kingpin Hospital) for a Biomedical Instrumentation Engineer as a Director of the Scientific and Medical Instrumentation Department of that particular hospital. After he has established a Scientific and Medical Instrumentation (S.M.I.) Laboratory in the "Kingpin" hospital and trained a technician to perform preventative and corrective maintenance, the Director is ready to repeat this procedure where S.M.I. Laboratories with trained technicians are established in all the member hospitals. The fact that each technician is employed by "his" hospital makes him take particular interest in that hospital. In contrast to the Central Stable Plan, the Nyack technician has a particular interest in every instrument and safety aspect of his technical environment. Working in one hospital, he becomes better acquainted and able to deal with particular situations in that hospital, has more opportunity for advancement, and becomes more well rounded in his field.

The Nyack Plan provides hospitals with their own biomedical instrumentation technician, thereby solving many of the equipment maintenance problems, and providing preventative maintenance and a safe electrical environment. Other

benefits not so evident are: reduced outside vendor repair costs, low cost to all hospitals in the Plan, reduction in malpractice liability, possible reduction in insurance premiums, seminars on safe use of instruments, data retrieval for analysis of repair costs, and information on whether devices are reliable or serviceable, and sharing of this data.

Kane[20], director of this New York based plan, points out that the costs involved in operation of a Central Stable Plan include the administrative and facility costs of a separate business and these must be paid by the member hospitals. Since the Nyack plan utilizes existing facilities and does not create as many additional separate business costs, it is much more feasible and economical. The only costs involved for the hospital are those of the technician and membership costs in the plan. Member hospitals also receive services of the Biomedical Instrumentation Engineer.

The Nyack Plan can be described in three phases. The first is the survey, which is a problem definition study period. The Biomedical Instrumentation Engineer conducts a qualification survey of the hospital wishing to join the plan and then presents a recommendation for acceptance or rejection to the Nyack Hospital Administration. The second phase is the implementation and training period. The member hospital is assisted in finding a BMET. He is trained by the Biomedical Instrumentation Engineer and familiarized with his hospital.

Follow-up, consultation, and education comprise the third phase in which the BMET is evaluated and assisted in any problem areas. Lectures on safety and use of instruments are given by the Biomedical Instrumentation Engineer at all member hospitals.

The Nyack Shared Biomedical Instrumentation Engineering Plan has been in existence for three years. Membership now consists of eight hospitals, within a 75 mile radius of the central hospital, encompassing four counties. As indicated by maintenance statistics, the mean time between failures has increased and the number of repairs has decreased.

Kane[20] indicated in the conclusion of his paper that like the Georgia State Legislature, New York state may soon require, by law, qualified instrumentation personnel to maintain instruments. It should be noted that the Nyack Plan only applies to facilities capable of financially supporting a BMET.

2.2.5 The Northwest Ohio Clinical Engineering Center

Unlike shared service programs in California, New York, and the Carolinas, the Northwest Ohio Clinical Engineering Center (NWOCEC) is a service and training center. This service is shared among the participating hospitals and might be viewed as a semi-Central Stable Plan. Incorporated in April of 1972 as a non-profit organization, NWOCEC originated over the growing national concern for the safety and reliability of medical electronic equipment used in

hospitals.[4] Alex Schwan[12], originator of the regional service center concept says that the center will be self-supporting at the end of the three year start-up period. The initial financing consisted of a $430,000.00 grant from the W. K. Kellogg Foundation.[23] Presently, each of twelve hospitals pay $14,000 per year for the center's services. In 1975, NWOCEC will have eighteen member hospitals. Located in Toledo, the Center has $70,000 in test equipment including two fully equipped mobile vans and a mobile laboratory facility.[24] Presently, two clinical engineers and seven biomedical technicians are available to: assist hospitals in equipment purchases; provide logged preventative maintenance records and other equipment information via a computer library; serve as a consultant; inspect and test new equipment before it is used in the hospital; provide educational seminars for hospital personnel operating electronics equipment; provide a 24-hour repair service; and maintain an inventory of spare parts and back-up equipment.[25] Four more persons will be added to the center's staff in its third year. One interesting goal is a "loaner" program to eventually include everything from suction machines to artificial kidneys and clinical laboratory apparatus.[24] "Loaner" programs provide hospitals with instruments for use when their instruments are not operating properly.

NWOCEC is a comprehensive regional service and training

center providing essential services to its members. It presently maintains its own facility, has three mobile facilities, and will eventually open two satellite branches. NWOCEC will soon permit all 29 hospitals in the Northwest Ohio region to participate in its self-supporting, non-profit organization. Although its immediate concerns will be intensive care and coronary care equipment, the center plans to accommodate all aspects of hospital equipment maintenance.

Information on this service made no mention of electrical safety services other than inspection of new equipment. At the time of this writing much of the step-by-step addition of services to the NWOCEC was being initiated, but no future plans were indicated for the addition of hospital safety checks or analysis.

2.2.6 Hospital Safety Testing Labs, Inc.

In contrast to the Northwest Ohio Clinical Engineering Center, Hospital Safety Testing Labs, Inc. (HSTL INC.) is a private corporation, presently serving mainly the Massachusetts area, dedicated to providing electrically safe environments in the hospital. Organized to provide a safe electrical environment in the hospital with a minimum involvement of hospital personnel, HSTL, Inc. offers complete electrical safety inspection programs including complete electrical/electronic safety surveys, critical area safety

testing, and equipment testing. Consulting services provided by the firm include prepurchase recommendations, evaluation of medical electronic instrumentation, electrical engineering recommendations, training programs, and other general hospital electronics consulting services. Equipment maintenance is provided on a contract basis; preventative maintenance program assistance is available for electronic instruments. Cardiac monitors are available for rental. HSTL, Inc., presently serves 30 Massachusetts area hospitals and conducts safety seminars at hospital association meetings and conventions, and nurses' and engineers' association meetings across the United States.[8]

HSTL, Inc., does provide one of the most needed services to the hospital, namely, electrical safety. It is a private corporation, a subsidiary of Bio-Design, Inc., a medical electronics equipment manufacturer, and performs its services for a fee or on a contract basis. It should be noted that the consultation service on instrumentation may be somewhat biased to Bio-Design.

2.2.7 Instrutek

Correspondence from Instrutek[26], a manufacturer of electronic test equipment for electrical safety testing, described an electrical safety service program for hospitals. The program includes electrical safety surveys, regional safety seminars, and training workshops for hospital personnel across

the United States. Instrutek provides complete electrical safety service for the hospital as a private company.

Regional seminars are conducted for engineering and maintenance personnel. Instrutek only charges travel expenses for its instructors when personnel from six or more hospitals attend.

Safety workshops are conducted for individual hospitals and include: general information on electrical safety; the use of medical equipment; compliance with codes, standards, and regulations; and administrative responsibilities in establishment of a safety test protocol for the hospital. Special sessions are conducted for engineering personnel concerning testing procedures for instruments and power systems, establishing a safety program, and demonstrations of some safety tests. The hospital pays travel expenses of the instructor and a flat rate per person attending. The flat rate was $75.00 per person at a recent two day workshop.

A more specific electrical safety training and safety survey workshop is also available from Instrutek. The cost of the workshop and survey is $150.00 per day plus expenses of Instrutek's engineer. A workshop is conducted the first day, covering the same material as the safety workshops in the previous paragraph. A workshop for medical and nursing staffs is conducted involving identification of electrical safety hazards, care in the use of electronic instruments, go - no go testing, and administrative regulations. The

remaining part of this workshop consists of an actual electrical safety survey of the hospital with the cooperation of the hospital's engineering personnel. Documentation of all tests is provided and recorded.

A fourth service of Instrutek is that of electrical safety service contracts, in which Instrutek performs a complete test of all instruments, power systems, and conductive materials in electrically sensitive patient areas of the hospital. Equipment and power system tests are made every six months in general patient areas.

2.3 Engineering Services in South Dakota

Although there are many elaborate and efficient engineering service plans in existence within the United States, many of them are not available for South Dakota, or if so are economically unfeasible. This thesis will show that there is a limited supply of engineering or technical assistance for South Dakota hospitals. The present methods involved in obtaining limited hospital engineering services may be of some consequence and will be discussed here.

2.3.1 Kreiser Surgical, Inc.

In a discussion with Mr. Brown of Kreiser Surgical, Inc., a hospital supply company, the author learned that the company services the medical electronic equipment that they sell, and sometimes other brands, but only on a general maintenance

basis. They are able to perform very little technical electronic troubleshooting, and rely on their "loaner" services to give them the necessary time to get repairs for the faulty equipment or send it back to the manufacturer. Some partial assistance is also received from a radio repair shop if the problem is electronic.

2.3.2 Sacred Heart Hospital

Mr. Ronald Morton, Administrator of Sacred Heart Hospital in Yankton, South Dakota, informed the author that he has a full-time electronic technician in his 155 bed hospital, performing electrical safety checks, preventative and corrective maintenance on all electrical and biomedical electronic equipment. He stated that his technician also assists the nearby Scotland, South Dakota, hospital with some of their biomedical electronic equipment problems. Mr. Morton indicated that his electronic technician was of great value in providing a safe and somewhat maintenance-free hospital. But, there were many questions and matters where the hospital would use a Consulting Biomedical Engineer if readily available, specifically to consider administrative and technical problems in building renovation, changing systems, new codes and standards, and equipment needs. One specific problem area was purchase, maintenance, and calibration of clinical laboratory equipment. Even though Sacred Heart Hospital had their own biomedical equipment maintenance and electrical

safety programs, Mr. Morton felt he could benefit from an engineering services program.

2.3.3 C. A. Hill and Associates

In conversations with Mr. C. A. Hill, an electrical engineer at St. Joseph's Hospital in Mitchell, South Dakota, the author learned that, in 1971, Mr. Hill and his associates had initiated a program of preventative maintenance and electrical safety checking for area hospitals. Letters were sent to Mitchell area hospitals introducing the program. When hospitals were followed up on this proposal, very little interest was found, and as a result the project was not pursued further.

2.3.4 Manufacturers' Services

Today there are a number of different manufacturers of biomedical electronic equipment. Each has separate provisions for servicing their equipment. Because of its complexity and intricate design, most of this equipment requires a factory service representative or biomedical technician, the latter being in short supply. Because of this short supply, the individual manufacturers have somewhat of a monopoly on the repair of their instruments. Consequently, charges include travel expenses, personal expenses, and excessive labor charges. Much of this equipment is old and requires frequent repair. Depending upon the complexity of the instrument, most manufacturers either send out a local

area service representative or sometimes one direct from the factory. Although an alternative to this situation is a service contract between the manufacturer and the hospital, Mr. Dimmitt of Gould, Inc., writes the author that this arrangement is too expensive for the small hospital. Local area service representatives are usually only located in the larger cities and are frequently hundreds of miles from faulty equipment. Mr. Dimmitt reminded the author that Gould's policy was not to supply "loaners," but to have rental units available; as the cost of the equipment made it very difficult to keep an extensive inventory for service use only. An exception to the rule was that of defibrillator repair, in which case a rental unit was supplied at no charge, due to the importance of the instrument.

Mr. Morton indicated that the service representative was usually the source of corrective maintenance in hospitals without a biomedical electronic technician, and that the repair costs were usually substantial mainly due to distances from repair centers. One exception to this location problem was that Mr. Morton's biomedical technician was an authorized service representative for American Optical Instruments. Although there are some instances like this in South Dakota, there is basically a poor supply of service centers or technicians for biomedical equipment.

2.3.5 Emergency Care Research Institute

The Emergency Care Research Institute of Philadelphia serves as a "consumers' union" of medical electronics. Part of its staff includes eight engineers, a physicist, and a physiologist, all engaged in testing medical electronic equipment and issuing a report in its monthly publication Health Devices. Approximately 1200 hospitals subscribe to this service at an annual cost of $265.00 each. Hospitals are able to compare different manufacturers' products and determine the best equipment for their needs by using the Health Devices publication. Recommendations for each instrument tested are given, and special advantages or disadvantages are noted in the publication. The Emergency Care Research Institute has greatly helped hospitals in determining which brand of instrument to purchase, and whether or not they were obtaining an accurate, efficient product.[27]

2.3.6 State Health Department

The Health Facilities Program of the South Dakota State Department of Health provides partial engineering services to the 62 licensed hospitals in the state. Their services consist of limited safety checks and consulting for codes, regulations, and procedures. Special assistance is given on construction projects; additional help is available for hospitals planning remodeling projects, renovations, or installations of new equipment. Engineers are employed to visit

the hospitals and make spot checks on biomedical electronic equipment for leakage current and noticeable defects on a routine or as-requested basis. This program has inspectors for specific areas of the hospital, including laboratory, x-ray, and electronic equipment as well as power systems and general facilities. A general facilities inspection is a prerequisite for licensing.

Although this service is helpful and used extensively, it cannot be specifically detailed in any one area. It must also cover such diverse areas as heating and cooling system maintenance, boiler efficiency tests, and construction advice.

Seminars in related areas of hospital electrical safety and maintenance have recently been conducted by the Health Facilities Program, in conjunction with the Department of Health, Education and Welfare and staff from South Dakota State University's Bioengineering Program in Electrical Engineering.

2.4 Rationale for Research

In discussing the various engineering services in the United States and those in South Dakota, it is obvious that South Dakota hospitals have few sources of complete or efficient engineering services. Because of the many small hospitals in this state and the distances between them, South Dakota has some problems particular to its geography, continental location, and level of business and industry.

Although many of the engineering service plans discussed are economical and feasible for many hospitals, they are not necessarily feasible for South Dakota hospitals. The Nyack Plan can be eliminated because each hospital cannot afford a BMET. The Southern California approach is efficient, but South Dakota's hospitals are spread over 67 counties and not over five. A Clinical Engineering Center would be attractive, but would have to provide safety services as well, and be more economical than $14,000.00 per member hospital. The regional approach of shared BMET's looks feasible, but would hospitals be interested in supporting an additional staff member?

It is the author's intention to investigate the situation of engineering services in South Dakota, analyze the most important needs, and consider a possible solution. It is hoped that available state resources can be used to provide these services, so that there is less reliance on outside vendors. It is evident that with current trends in hospital standards and accreditation requirements, hospitals may soon be bound to obtain the engineering services discussed, or lose their license! In an attempt to assist the improvement of health care delivery in South Dakota, this author will investigate the present situation and try to make some effective, efficient and economical recommendations and conclusions.

CHAPTER III

METHOD OF INVESTIGATION AND SUMMARY OF RESULTS

3.1 Introduction

A survey of engineering service needs in South Dakota was conducted via a questionnaire. Preliminary survey information about these needs was obtained from Dr. D. E. Sander of the South Dakota State University Electrical Engineering Department (Bio-Engineering Program), and John Robertson and Ray Scott, engineers with the Health Facilities Program of the State Health Department of South Dakota. General indications were that many different engineering services were needed, hospitals had limited financial resources, and many people were not aware of all the possible electrical hazards in the hospital.

The questionnaire was general in nature, and was divided into two sections: Electrical Safety and Electronic Maintenance, and Instrumentation. It introduced a possible charge for a minimal engineering service program and asked questions concerning equipment supply and inventories.

Questionnaires were sent to 62 state licensed hospitals in South Dakota. A follow-up reminder was also sent. Twenty-six questionnaires were returned with only a few being completely filled out. The questions answered were not consistent; consequently, the results obtained are based on

the total responses received from the survey questionnaire.

3.2 The Questionnaire

This chapter will present each specific question, or section, give its intended meaning, and present the general results obtained. Please note that the results are strictly a summary; the evaluation follows in chapter IV. When possible, the results of the questionnaires returned will be placed in the answer blanks of the question.

Question I.1a. /Does your hospital perform routine visual electrical safety checks? Yes(22) No 3)_7

Intent: Intentions were to determine if the hospitals, presently conduct routine visual safety checks on cords, plugs, outlets, electrical boxes, appliances, devices, instruments, and any other item related to electricity.

Results: Results were 88% positive. Although the checks should be unavoidable, there were still some negative replies. This question may have been interpreted quite broadly.

Question I.1b. /Does your hospital perform routine ground integrity checks? Yes(11) No(14)_7

Intent: Intentions were to determine the number of hospitals checking their electrical systems to verify that the grounding conductor was continuous from the location of test to earth

ground. This test is also important for CCU and ICU areas.

Results: Results were 31% positive. Of the positive responses received, most were from the larger hospitals.

Question I.1c. /Does your hospital perform routine outlet polarity checks? Yes(10) No(15)_7

Intent: Intentions were to determine the number of hospitals performing outlet polarity checks by verifying proper voltage potentials for each female connection of the wall outlets and receptacles.

Results: Results were 40% positive. Most of the positive responses received were from the larger hospitals.

Question I.1d. /Does your hospital perform routine current leakage checks on electronic instruments? Yes(8) No(16)_7

Intent: Intentions were to determine the number of hospitals that measure the amount of leakage current, in an electric device or biomedical electronic device, passing from the instrument's case or chassis to ground.

Results: Results were 33% positive. Most of the positive responses received were from the larger hospitals.

Question I.2. /Which hospital department is responsible for those checks and what is the title of the person in charge?/

Intent: Intentions were to determine whether or not there was a special department for electrical safety checks, or if there was even a separate department for electrical maintenance. It was intended that the title of the person in charge would indicate responsibilities.

Results: Most of the responses to this question indicated that the maintenance department was responsible for the checks, if performed, and the titles consisted mainly of "Maintenance Man," "Chief Engineer," "Engineer," and "Electrician."

Question I.3a. /What is the number of personnel involved in (may be some overlapping) electrical maintenance?/

Intent: Intentions were to determine the number of people involved in general electrical maintenance in each hospital. Although these people may have been involved with other maintenance areas, the author attempted to determine how many persons, if any, were dedicated to this specific area. It was assumed that these people would have additional duties.

Results: An average of 1.9 people per hospital were involved in electrical maintenance.

Question I.3b. /What is the number of personnel involved in (may be some overlapping) medical electronic instrument repair and maintenance?/

Intent: Intentions were to determine the number of people involved in electronic instrument maintenance in each hospital. Although these people may have been involved with other maintenance areas, the author attempted to determine how many persons, if any, were dedicated to this specific area. It was assumed that these people would have additional duties.

Results: An average of 0.8 people per hospital were involved in medical electronic instrument repair and maintenance.

Question I.3c. /What is the number of personnel involved in (may be some overlapping) TV, and other electronic repair and maintenance?/

Intent: Although these persons may have been involved in other maintenance areas, the author attempted to determine how many persons, if any, were dedicated to this specific area. It was assumed that these people would have additional duties.

Results: An average of 0.9 people per hospital were involved in TV, and other electronic repair and maintenance.

Question I.3d. /What is the number of personnel involved in (may be some overlapping) electrical safety checking?/

Intent: Intentions were to determine the number of people involved in electronic safety checking in each hospital. Although these people may have been involved with other maintenance areas, the author attempted to determine how many persons, if any, were dedicated to this specific area. It was assumed that these people would have additional duties.

Results: An average of 1.5 people per hospital were involved in electrical safety checking.

Question I.4. /Would you like to make additional and more extensive electric safety checks on your medical electronic instruments, power outlets, and grounding systems in your hospital? Yes(17) No(5)/

Intent: Intentions were to determine if the hospitals surveyed were interested in, or wished to conduct, more electrical safety checks of their hospital.

Results: Results were 77% positive.

Question I.5. /How do you solve service problems on your present medical electronic instruments? (Please indicate the relative percentages each solution contributes.)/

28% a) Have the hospital's electrical technician repair it.
3% b) Discard the faulty instrument permanently.
31% c) Contact the company you have a maintenance contract with.
21% d) Contact the manufacturer and ask them to send out a service representative.
17% e) Contact a local or nearby electronic technician, TV repairman, etc.

Intent: Intentions were to determine which methods, and to what percent, the listed solutions were used to solve service problems in the hospitals.

Results: Solutions "c" and "a" were most common. Solution "b" was least common.

Question I.6. /Would you like to have this same engineering services program provide efficiency tests and routine maintenance on your heating and cooling system? Yes(12) No(8)_7

Intent: Intentions were to determine if the hospitals would like engineering services comprising areas other than biomedical electronic and electrical areas, specifically heating and cooling systems.

Results: Results were 60% positive.

Question I.7. /Number in order of importance the areas your hospital needs an engineering service program for: (1 is most important)_7

1 Electrical Safety Analysis
2 Electronic Instrument Maintenance
3 Heating System Maintenance
4 Cooling System Maintenance

Intent: Intentions were to determine the most needed services of an engineering service program dealing with four problem areas.

Results: Needs for electrical safety analysis were considered most important; cooling system maintenance needs were considered least important.

A Cost Estimate. This section of the questionnaire introduced a proposed plan of engineering services based on general needs of the hospital. (Refer to Appendix B, page 98). The plan included one annual electrical safety analysis of all patient and staff areas including current leakage measurements of any electrical equipment, ground continuity and integrity checks, outlet polarity and condition checks, and a visual inspection of all other electrical apparatus. Engineering consulting and technical services for electric biomedical equipment and a 24 hour service line were proposed. Maintenance for medical electronic instrumentation was also included in the plan on a service contract basis or at a $15.00 per hour labor charge plus expenses. Administrators were asked to calculate their hospital's total cost by filling in appropriate numbers for bed size, number of operating and recovery rooms, coronary care units, etc., and by totaling the results. Rates for each different area were based on an estimated average length of time to perform the test or check, at an hourly rate of $15.00 to $20.00 per hour. The amount of time needed to conduct each check was estimated as follows: one-half hour for each general patient bed, four to five hours for each operating and recovery room, two to three hours for each delivery and emergency room, one hour for each

intensive care unit (ICU) or coronary care unit (CCU) bed, four to five hours for each physical therapy area, two to three hours for each laundry area, four to five hours for each kitchen area, and four to five hours for each laboratory. Rates for kitchen, laundry, physical therapy, and laboratory areas were tripled for Sioux Valley and McKennan Hospitals in Sioux Falls, and doubled for Sacred Heart Hospital in Yankton because of their large size. Questions 8-12 of the questionnaire were directed at the cost estimate all hospitals were asked to make. Twenty-three cost estimates were received during the survey. They ranged from $455.00 to $6,280.00 per hospital. Of the total 1,889 beds indicated, 1,340 were from six hospitals with over 100 beds, the remaining 549 beds were from 17 hospitals with less than 100 beds each. The average cost per bed per year for hospitals over 100 beds was $16.98. The cost was $21.89 for hospitals under 100 beds. The average capacity of the hospitals under and over 100 beds was 32 and 223 beds, respectively.

Question I.8. /Would you find this yearly cost a reasonable rate for the described services if you were required to make the listed safety checks and tests of your hospital and instruments? Yes(17) No(7)_7

Intent: Intentions were to determine whether or not the calculated cost for their hospital would seem reasonable if they were required to make

the listed safety checks and other tests of their hospital and instruments for accreditation or other regulatory requirements.

Results: Results were 71% positive.

Question I.9. /Would you find this cost a reasonable rate for the described services if you were not required to make the listed safety checks of your hospital and instruments? Yes(12) No(12)_7

Intent: Intentions were to determine whether or not the calculated cost for their hospital would seem reasonable if they were not required to make the listed safety checks and other tests of their hospital and instruments for accreditation or other regulatory requirements.

Results: Results were 50% positive.

Question I.10. /Could this program reduce your administrative costs? Yes(0) No(13) Don't know(9)_7

Intent: Intentions were to determine if the proposed program could reduce the hospitals' administrative costs.

Results: Results were 0.0% positive and 40.9% "don't know." Many administrators apparently felt that any extra cost would not reduce his administrative costs.

Question I.11. /Does the cost seem attractive to you presently? Yes(2) No(15) Don't Know(5)_7

Intent: Intentions were to determine if the hospital was aware of the necessity of these services.

If so, the estimated costs should have been quite attractive.

Results: Results were 10% positive and 23% "Don't know." Again, the administrator apparently felt that any extra cost would not be attractive.

Question I.12. /Do you think you could obtain the same services more economically in some other way? Yes(12) No(2) Don't Know (9)_7

Intent: Intentions were to determine if administrators thought they could obtain the same services in a more economical way.

Results: Results were 52% positive and 39% "Don't know." A surprising fact was that seven of these 12 positive responding hospitals did not have these services, and yet they thought they could obtain them more economically some other way.

An Instrumentation Chart. This section of the questionnaire was intended to determine a general inventory of hospital instruments in South Dakota, and specific information relating to the instrument's performance.

A blank chart (See Appendix B, page 99) was presented with a list of hospital instruments with columns that could be filled in for the requested data. Administrators were asked to indicate: leased, owned, or rented

equipment, and which type was preferred; the number of each instrument in the hospital; the number in need of repair or replacement; the number being replaced in the next year; the average number of service problems per year per instrument; the average usage per month of that instrument; and the average lifetime of each instrument.

Intentions were to determine the extent of instruments, their usage, and the amount of service problems encountered. This section of the questionnaire was too long, and results were few and incomplete. It was noted that most instruments were expected to last at least ten years, and most of the instruments were used daily except for defibrillators and other very specialized instruments. Almost everything was owned and no other preferences were indicated. Results from this section were basically invalid because of minimal completions of this section by those surveyed.

Question II.2. /What is your preferred means of obtaining medical electronic instruments at these costs?/ (Prices between $0.00 to $50,000.00 were listed with 3 columns to check if purchase, rental, or lease was preferred.)

Intent: Intentions were to determine how South Dakota hospitals most commonly obtained their medical electronic instruments, and if there was a point at which their preference changed.

Results: Generally most hospitals preferred to purchase equipment valued up to $25,000.00. Above that, equal results were obtained between purchasing and leasing.

Question II.3. /What equipment do you have under service contracts, or lease, for how long is the equipment leased, and is service included in the lease?/

Intent: Intentions were to determine how much hospital equipment was leased in South Dakota or under a service contract.

Results: Poor results were obtained with four or five people indicating an autoclave under a service contract, or sometimes a heating system. Some clinical laboratory equipment was listed, but again only four or five instruments.

Question II.4. /Do you think an engineering services program should provide for the supply of medical electronic instrumentation? Yes(13) No(8)/

Intent: Intentions were to determine if hospitals would like to obtain their instruments through an engineering services program.

Results: Results were 62% positive. This question helped determine whether or not the author's initial proposed engineering services plan should include the supply of medical electronic instrumentation.

Question II.5. /Would you feel it advantageous to have all the engineering services needed by the hospital handled by one organization? Yes(17) No(4)_7

Intent: Intents were to determine if hospitals felt it advantageous to have all the engineering services needed handled by one organization.

Results: Results were 81% positive.

COMMENTS

Intent: Intentions of this section were to invite comments on the proposal, the services, or any other subject relating to the questionnaire.

Results: Many comments were received throughout the questionnaire and also in this section. Most related to the general plan proposed and were indications of whether or not such a plan was needed. Section 3.3 presents these comments in a more detailed form.

3.3 Interesting Comments from the Questionnaire

Some of the questionnaires were returned with general and specific comments on the engineering services proposal. Although some of these comments were very general, the author will present them for the reader's benefit.

Some questionnaires came back partially completed with phrases like "too long" and "too much detail." One abused page of the questionnaire was returned in an envelope with

"No! No! No! Stick to your school and leave hospitals alone!" Some comments indicated that there was just not enough time available to complete the questionnaire. Others were more contributive to the survey and indicated that they did not need engineering services as they had a technician take care of the hospital. One hospital made its calculation for the proposed engineering service and commented that it would only increase the cost per patient-day ten (10) cents. Another hospital indicated that it could obtain some of the checks more economically but not all of them. Two of the larger hospitals indicated that they presently had a technician employed, but they could definitely use the consulting services of the program. Many questionnaires stated lack of understanding and interpretation of instrument problems as being an area in which they would like more professional guidance and assistance, not necessarily desiring a complete repair service. Other comments suggested that the hospital personnel could perform some of the safety checks, some of the corrective maintenance, and most of the preventative maintenance, if someone would educate hospital personnel on the fundamental concepts and procedures involved. Another administrator indicated that maintenance services were in "sad condition," but he felt better education of his staff on the equipment and its usage would solve the majority of problems. He said that engineering services are not a necessity. Many

questionnaires were returned without comments, and some indicated that an engineering services program was not economical or feasible for anyone. Yet, others mentioned that these services could only be advantageous if the services performed were certified and documented. One hospital administrator thought his needs would be better solved by an industrial engineer, but he had electronic help available in his facility. "An engineering services program could be very useful in South Dakota hospitals," commented another administrator. He indicated that although his hospital presently conducts safety checks and has an electronic technician nearby, he would possibly be interested shortly in the proposed service.

3.4 Questionnaire Critique

The questionnaire was designed to determine the engineering services needs of South Dakota hospitals. Four general areas of concern were involved, and two questions in other than electrical areas were included to determine if those services could be considered more in need. Generally, good results were obtained, with approximately 45% of all questionnaires returned. The questionnaire was complicated, some sections being long and others general. This research was originally intended to conduct a feasibility study for a predetermined engineering services program. The questionnaire was intended to survey state

hospitals concerning their needs for engineering services, and result in a decision as to the feasibility of such a program. Based on later research and results from the questionnaire, this study was modified prior to the writing of this thesis. Intentions of this study reverted to surveying the engineering services needs of South Dakota hospitals and presenting a feasible optimal plan for them. Thus, the questionnaire could have been more specifically designed for this purpose. A follow-up questionnaire could have been helpful, but the time limits of this thesis made it prohibitive.

CHAPTER IV

EVALUATION OF RESULTS

4.1 Introduction

The results of the survey taken will be evaluated and presented in this chapter. The initial engineering services program, introduced by the questionnaire in four parts, will be discussed. Data received from the questionnaire will be evaluated accordingly for the four areas of concern. These four areas were determined from preliminary discussions with John Robertson and Ray Scott of the Health Facilities Program of the State Health Department, and Dr. Duane E. Sander of the South Dakota State University, Electrical Engineering Department. Conversations with Mr. Brown, Mr. Morton, and Jan Clites, a South Dakota State University Nursing Instructor, also contributed to the initial plan. Each of the initial four areas of the proposed engineering services plan will now be discussed. Results obtained from the questionnaire will be evaluated and analyzed.

4.2 Electrical Safety Analysis

In the introduction to the questionnaire, the topic of electrical safety analysis was described to include analysis of the hospital environment and all electric and electronic instruments, and detection and prevention of electrical hazards to patient and personnel. The survey indicated that few

hospitals conducted even marginal electrical safety checks consisting of outlet polarity or ground integrity checks. In general, the positive indication for more of these safety checks told the author that the administrators returning the surveys were knowledgeable of the potential electrical hazards, although many did not have an electrical safety program. This is evidenced by the 1-1/2 persons per hospital involved in electrical safety checking. General comments from the survey were interpreted as being somewhat protective of the present situation in each hospital. Although some comments indicated that hospitals were unknowledgeable of certain electrical safety hazards, most of these comments indicated that there was a desire to learn more. Even though many thought an engineering services concept was good, some hospitals suggested that their own personnel were capable of these checks. Electrical safety analysis was listed first in order of importance as the most needed engineering service.

In evaluating survey results, the following conclusions were made concerning electrical safety analysis:

1. South Dakota hospitals are aware of electrical hazards in general, but more knowledge is desired by a large majority of hospitals.
2. Most South Dakota hospitals do not perform adequate electrical safety checks of their instruments or environment, but would like to do so.

3. South Dakota hospitals need educational and instructional assistance to provide the hospital staff with adequate knowledge of electrical safety requirements in the hospital environment, and to provide the hospital staff with the technical knowledge and skills necessary to perform these requirements.
4. South Dakota hospitals are negative to additional costs for electrical safety services. Existing maintenance staffs should be utilized as much as possible, in an attempt to solve the problem locally without bringing in additional outside costs.

4.3 Preventative and Corrective Maintenance for Biomedical Equipment

This section of the survey introduced a routine and corrective maintenance service for medical electronic instruments. Results obtained indicated that there was less than one person per hospital performing electronic, TV, or medical electronic instrument repair and maintenance. The hospital electrical technician performed service work 28% of the time, and local electronic technicians or TV repairmen performed the service work 17% of the time. The majority of the 28% contribution by hospital electrical technicians to the solution of service problems in medical electronic instruments was made by the larger hospitals who had specialized electronic technicians or engineers on the staff. Maintenance contracts played a significant role (31%) in providing service,

but few (17%) electronic technicians were utilized. Equipment items serviced by contract were listed as an autoclave, x-ray machine, or clinical laboratory instrument. Therefore, the highly specialized equipment has been serviced by the manufacturer, quite routinely, but the more general types of equipment have been serviced by a variety of people. Generally most service came from the manufacturer one way or another, although personnel in the hospital and surrounding area played an important role in service assistance. Some indications were that hospital personnel would perform some maintenance if they had some knowledge of what to do.

The following conclusions were made concerning preventative and corrective maintenance after evaluating the survey, its results, and comments.

1. Provisions for biomedical electronic instrument repair in South Dakota hospitals are inadequate. Manufacturer services are not economical or fast.
2. There are few existing preventative maintenance plans in South Dakota hospitals, and extremely few biomedical electronic technicians performing corrective maintenance on faulty instruments.
3. A preventative maintenance program for each hospital would familiarize existing staff with biomedical electronic instruments, their operation, and functions.

4. Educational and instructional assistance in preventative and corrective maintenance would be of benefit to existing maintenance personnel in South Dakota hospitals. Corrective maintenance would not have to be specific to help solve many of the general problems arising.
5. A secondary source of information and technical assistance should be available to hospital maintenance staffs for solution of special problems and performance of exotic or specialized tests. A mobile technical facility may be feasible.
6. Outside vendor maintenance costs are high. Existing maintenance staffs should be utilized as much as possible in an attempt to solve the problem locally without bringing in additional outside service costs.

4.4 Consulting and Technical Services

Engineering consulting and technical services are a rather general addition to the engineering services introduced by the survey. Although there were no specific questions on consulting and technical services, some comments were directed toward this phase of engineering services indicating that sources of engineering consulting were scarce, unfamiliar with hospital systems, or too expensive. Hospitals have many questions in which professional advice is needed. Likewise, many technical decisions are made without engineering

considerations. Consulting can assist administrators purchase new equipment, make engineering decisions on old instruments, and provide a source of general hospital engineering. Consulting and technical services could also provide answers and knowledge to many less familiar hospital personnel.

These conclusions on consulting and technical services were made after evaluating the survey, its results, and comments.

1. South Dakota hospitals need the consultation and technical services of a professional bioengineer, and/or experienced biomedical electronic technician.
2. Engineering consulting and technical services could provide educational and instructional assistance for electrical safety analysis, preventative maintenance planning, general maintenance problems, building renovations and installations of new biomedical equipment.
3. Although there are some engineering consulting and technical services available in South Dakota, none are specifically oriented for hospital problems or biomedical considerations. A South Dakota engineering consulting and technical service should be available to the hospitals.

4.5 Supply of Medical Electronic Instrumentation

Biomedical electronic equipment can be purchased, rented,

or leased. Almost all of the biomedical electronic instruments in South Dakota hospitals are owned. This basically accounts for some manufacturers' service delays, in that once a product is purchased, the manufacturer does not have as much responsibility to the customer for the instrument's proper operation as he does when it is leased or rented. In rental and leasing cases, charges are based upon a functional instrument, and service demands will usually be satisfied sooner. Leasing and renting can provide hospitals with needed instruments, but after a certain amount of time, usually much less than the instrument's lifetime, the charges for renting or leasing equal the purchase price. There are some service and financial benefits from leasing or renting. Rental involves a monthly charge for the use of the instrument; it is not as common as leasing because it is usually more expensive over a period of time. The rental is more popular for periods shorter than one year and does not involve a formal, binding agreement. Leasing involves a monthly charge for use of the instrument which may be applied to the purchase of that instrument at the expiration of the lease. Leasing charges sometimes include maintenance of the instrument or a service contract. Some lease arrangements serve as extended rental arrangements. The benefits of leasing are conservation of working capital, and avoidance of maintenance responsibilities.

A lease agreement is usually binding and includes finance charges.

Whether they lease, rent, or purchase their equipment, hospitals need a reliable supplier of medical electronic equipment. The survey indicated that 62% of the hospitals felt an engineering services program should provide for the supply of medical electronic instrumentation. It is believed that this function should consist mainly of purchase assistance and group purchase advantages, as well as a liaison between the manufacturer and an engineering services organization with the hospital's interests in mind.

These conclusions concerning the supply of medical electronic instrumentation were made after evaluating the survey, its results, and comments.

1. Hospitals could use assistance and engineering guidance for interpreting specifications and obtaining the best medical electronic instrument for their dollar.
2. An engineering services program should provide for the supply of medical electronic instrumentation through a consulting service, and offer its consulting and technical services for obtaining instruments best suited to the purchaser.
3. Considerations should be given to cost benefits and service advantages of leasing or renting, and group purchasing.

4.6 Evaluation of a Proposed Engineering Services Program

Of 24 hospitals completing a cost estimate for electrical safety services, 71% indicated that the cost was reasonable if they were required to have the specified services available to their hospital. These requirements could be stated by Federal or State governments, or the State Health Department. Specific accreditation standards are now required by the American Hospital Association and the Joint Commission on Accreditation of Hospitals for hospitals desiring accreditation by these groups. The questionnaire results indicate that the services specified are not available in South Dakota because they are not required for hospitals unconcerned about specific accreditation standards! Apparently, these standards are too demanding for South Dakota hospitals. When asked whether the cost was reasonable if the safety services were not required, 50% replied that it was, 50% replied that it was not! Again, this seems to indicate that some hospitals would not avail themselves to the specified safety services at any cost, in spite of its importance.

Although 39% didn't know; 52% of 24 responses indicated that hospitals could obtain the safety services in a more economical way. If true, why weren't they doing so? Apparently the same reason again holds; that the safety services are not mandatory.

The average bed capacity of the 24 hospitals completing

the survey was 82.1 beds. Five of the hospitals indicating positive results on the required services cost were already conducting these services. Yet, they found our estimate more reasonable.

These conclusions were made after evaluating the survey, its results and comments.

1. Hospitals found the safety services cost reasonable if the services were required.
2. Hospitals were split concerning the economic advantage of safety services when the services were not required.
3. The cost estimate used was economically attractive to the hospitals in comparison with their present costs.
4. The hospitals having no existing safety program may not be qualified to judge the economic attractiveness of the proposed engineering services program.

4.7 Specific Indications of the Survey and Suggestions

Results, from the survey taken, indicated that engineering services were needed in South Dakota, but that hospitals did not want to lose any of their present personnel positions by bringing in an outside vendor of these services. In general, most hospitals wanted electrical safety services but wanted them performed by their own personnel, and wanted a source of education or instruction for their staff. Likewise, engineering consulting and technical services could be of

great aid. Assistance in general and preventative instrument maintenance is also needed for the hospital maintenance staff. It is believed that a strong preventative maintenance program could alleviate many unnecessary service problems; general maintenance training could allow hospital maintenance staffs to do some troubleshooting of biomedical electronic instruments. Of primary importance would be a mobile service facility to handle maintenance problems and do major repair work in an attempt to provide better instrument performance and less "down" time for the hospitals needing it.

CHAPTER V

FEASIBLE PROGRAMS FOR ENGINEERING SERVICES IN SOUTH DAKOTA

5.1 Some General Considerations Revisited

The literature review discussed various engineering services, their basic design, purpose, and success. Special thought should be given to each service plan and why it was best for its area. Likewise special thought must be given to an engineering services program for South Dakota; its features must enhance South Dakota's health care delivery and the environment in South Dakota hospitals.

5.2 Application of Engineering Services Plan to South Dakota

General advantages and disadvantages of each engineering service program as they related to South Dakota were mentioned in section 2.5. These will now be discussed and optimal aspects of these plans will be determined for South Dakota.

Probably the most needed services in South Dakota hospitals are those of the biomedical electronic technician (BMET). Of second importance are those services of the bioengineer. However, each hospital cannot afford their own BMET, and even if they could, he would not be kept busy with biomedical electronic work. This is because many

hospitals do not have enough instruments, technical problems, or safety needs to merit a full-time BMET on the staff. A few larger hospitals are exceptions: because of their size and complexity these larger hospitals have both sufficient need and enough work for a BMET.

The principle of one BMET for each hospital is basically that of the Nyack Shared Engineering Plan. It is applicable to only the large hospitals in South Dakota which are a minority and also far apart. In reviewing aspects of the Nyack plan for South Dakota, these points should be noted:

1. Because a BMET cannot be placed in each South Dakota hospital, the pride in having his own hospital and a particular inherent interest in it is not a feasible benefit for most South Dakota hospitals, although every attempt should be made to perpetuate this feeling in larger hospitals. Because of the familiarity factor, it may be desirable for a BMET's hospitals to always be the same; i.e., he works in a specific area or region.
2. Hospital costs for these services are less if they originate through a hospital organization, are set up in the hospital, and are not provided by a separate private business. This method emphasizes reduced outside vendor repair costs and could lower malpractice liability.

3. A Central Stable Plan approach is questionable because of the large distances between hospitals and the additional costs involved.

Because the Southern California approach was designed for 70 hospitals in five counties, it is not directly applicable for South Dakota, but its central stable approach for a shared service deserves note. These advantages can be utilized for South Dakota.

1. Providing services as needed, not on an amount allotted basis, is both efficient and economical for hospital and service organization.
2. Area educational and industrial resources must be used to their fullest to establish complete and extensive services.
3. Short distances between hospitals made the Southern California approach efficient, even though it was a type of Central Stable plan. Special considerations should be given to "regionalization" of available services in South Dakota.
4. Qualified engineering guidance should be readily available when needed.

In viewing CHESS, the Carolinas Plan, an important aspect worth noting is that of complete plant engineering assistance in other than biomedical electronic and biomedical engineering consulting areas. A source of plant engineering services is also needed by South Dakota

hospitals, as their problems are not only in electrical, electronic, or safety areas. Although the fee per hospital was about one-half the salary of a full-time BMET, the CHESS plan provided the necessary engineering services. Electronic repair service was available at an additional hourly charge.

The Massachusetts approach had similar considerations in their pilot study. The Massachusetts plan provided engineering services on a regional basis with shared technicians. This regional approach for South Dakota would be more economical than one BMET per hospital, but the cost would still be prohibitive, and many other engineering services would still not be available.

The Northwest Ohio Clinical Engineering Center (NWOCEC) presented a thorough solution to the problems of electronic instrument repair and maintenance. Specific merits of this system are listed in consideration of unique South Dakota problems.

1. Mobile service facilities provide an optimum maintenance situation. No transportation problems are involved and there is a minimum of "down" time. Likewise, faulty instruments can be repaired in their own environment. This type of arrangement would be very useful in South Dakota, but with the small hospitals in mind, a $14,000 member fee makes the system unfeasible. Service problems are

not extensive enough in South Dakota hospitals to merit this charge nor are budgets flexible enough to accommodate it.

2. A training center is a good foundation for further education of hospital personnel.
3. An extensive preventative maintenance program with efficient record keeping is a necessity.

5.3 Observations and Recommendations

From the survey taken, conversations with various persons, and other investigations of the thesis, these observations and recommendations are made on engineering services for South Dakota hospitals.

1. Present hospital maintenance staff can perform many of the electrical safety checks, if they could obtain instruction on the procedures involved and interpretation of the results.
2. Present hospital maintenance staffs could do some actual service work on biomedical electronic equipment if they had instruction in fundamental repair and maintenance procedures. A preventative maintenance program could benefit hospitals, and assist the corrective maintenance program. It would also reduce the number of maintenance problems.
3. Engineering consulting and technical services could

provide more efficient solutions to hospital problems, and avoid expenses accrued from unprofessional and uneconomical engineering decisions.

4. A source of statewide education in aspects of biomedical engineering in the hospital environment is needed for all hospital staffs.

5. A well trained experienced staff of BMET's should be available to hospitals for the corrective maintenance of biomedical instruments. A mobile vehicle approach may be optimal, making visits to all hospitals on a routine basis.

6. Efforts in the above five areas should be assisted by state universities, the Health Facilities Program of the State Health Department, and the hospitals themselves as much as possible. Outside costs should be kept minimal by increasing the utilization of existing expertise. This also suggests that the organizational structure should be nonprofit.

5.4 Some Feasible Plans

In attempting to determine feasible solutions to engineering service needs for South Dakota hospitals, there are many solutions. The number of available solutions decrease with increased concern over costs. Feasible solutions will be presented with general cost considerations assuming that the availability of funds from all sources, if not available

in a lump sum to initiate a complete program, will be available on an increasing basis as the particular plan expands to its full capacity. Likewise, if present funds are limited, the available options will be fewer.

Two possible solutions are evident. One is the application of the shared BMET or regional approach. A group of five or six hospitals would hire one BMET who would travel from one hospital to another. Specific problems would be encountered in areas of the state where the hospitals are 75 miles apart. These hospitals would have to furnish some test equipment and a facility for the BMET. The BMET could possibly be shared by 5 or 6 hospitals if his tasks were only critical area safety checking, biomedical electronic instrument corrective and preventative maintenance, and general advice. If a group of six hospitals participated, a BMET would cost about $12,000 annually[28] plus another $8,000 in expenses, or for six hospitals the cost would be $3,333.00 per hospital. Although many hospitals might find this figure high, it is minimal and probably one of the more economical means right now. It should be noted that having six work areas, many of them in small towns, might not appeal to very many BMET's, but it is one possible solution which hospitals could take advantage of now.

The remaining alternative, and seemingly the better,

would be supported in part by a specialized education and training program for existing staff of South Dakota hospitals on general areas of electrical safety and maintenance. Hospital staffs could be taught general maintenance procedures and troubleshooting principles. A majority of problems could be eliminated with a general troubleshooting approach. Consulting and other assistance could be received from the bioengineering program at SDSU, its extension service, and the State Health Department at Pierre. A possible on-the-job training program could be established with bioengineering students. A hospital would not have solved all of its serious instrument repair problems though, nor would it have available consulting help on the job.

The latter of these programs seems to have the potential for an applicable program, and it is with this idea that the optimal plan is presented.

5.5 An Optimal Plan - In Three Phases

The following plan is presented as an optimal approach to providing engineering services to South Dakota hospitals. The plan will be presented in three phases for implementation.

Phase I. Education and training. This phase would establish maintenance training seminars for members of hospital maintenance staffs and safety training for

the nursing, administrative, and medical staff. This would provide the necessary background in biomedicine to help the staff understand functions of the instrument. Basic seminars on electricity, electronics, and bioengineering would also be given. Preventative maintenance principles would be taught for all maintenance staffs and special training on applying these principles would be given. Training would include proper procedures for complete electrical safety checking of the hospital environment. Training in the principles of basic troubleshooting and the modular approach to servicing would also be given. This phase would be of a continual nature, offering these seminars on a regular basis, possibly semi-annually. A possible addition to this would be a regular newsletter with basic technical helps, general instrument theory or recent developments in the field with special emphasis on maintenance approaches. This phase would not eliminate any of the present maintenance personnel or require additional personnel. The costs would only be those of education and instruction.

This phase of services could benefit the hospital by allowing it to make its own electrical safety checks and perform routine and preventative maintenance with its own staff, avoiding additional expenses

for outside services and maintenance personnel. Likewise, presently available in-state resources would be used to provide the educational background for hospital personnel rather than obtain it from outside sources. This would be an efficient, economical, and feasible provision for these services.

Phase II. Phase II would consist of the establishment of a Regional Engineering Center. This phase would be initiated during phase I. The Regional Engineering Center would be established in an area central to the majority of hospitals in the state, possibly in Mitchell or Pierre in close proximity to the Health Department engineering staff. Services provided would consist of engineering consulting for prepurchase recommendations, hospital renovation and remodeling, instrument analysis and studies, and general maintenance advice. The engineering services would provide assistance with special problems in maintenance and the hospital environment. This center would also establish a calibration and standards laboratory for all hospitals, and would coordinate this program with the two engineering schools in the state. Engineers from this service center would also plan for phase III and help to initiate that phase. They would purchase initial

instrumentation and vehicles for the third phase. Likewise, the engineering staff of the Regional Service Center would be responsible for acquiring three BMET's for phase III and training them in specialized aspects of the program and services offered. BMET's would probably be hired in the mid-year of phase II.

Phase III. With termination of phase II, phase III would initiate a mobile service vehicle program by which three BMET's would provide coverage of three different areas of the state with two mobile service facilities. Each BMET would be responsible for a particular area. The mobile service facility would make routine visits at each hospital in the state, repairing faulty biomedical equipment, assisting maintenance staffs with preventative maintenance problems, conducting special safety checks and tests of biomedical electronic equipment. If not initially available, the center could eventually provide special assistance for nuclear medicine instruments, x-ray, and other specialized clinical laboratory apparatus. This would be accomplished by sending the BMET's and some members of the engineering staff to manufacturers' seminars and refresher courses on maintenance of their equipment.

Possible future additions to these services would be

computer assistance in hospital inventories and preventative maintenance responsibilities as well as extension of consulting services into heating and cooling systems.

This engineering services program would be implemented over a three year period, with each phase comprising one year's time. The program would be able to start at minimal costs and increase its scope over the three year period as the program becomes better known and utilized.

5.6 Financial Considerations

In the best interest of all hospitals, immediate implementation of this engineering services plan would be ideal. Some possible sources of funding would be governmental health departments, or legislatures. Private sources are also available, such as endowments or special foundations. The W. K. Kellogg Foundation of Battle Creek, Michigan, has been very active in the support of shared engineering services, providing grants to engineering service programs in Massachusetts, Ohio, the Carolinas, and Southern California. This foundation has provided the majority of support for the first three years of these services with the intent that such a service would be self-supporting after the initial start-up period.

Although various sources of funding may be available for initiation of such a program, the availability of

these funds will decrease after the initial implementation and start-up period. It is obvious that unless this program was completely subsidized by a state or federal source, the costs of this program would have to be borne by the hospital, at least partially, after a period of time. The smaller hospitals would probably be required to support the majority of the program since four or five of the larger hospitals have their own electrical safety and maintenance programs presently. If the five large hospitals are not included in a program, then these hospitals, totalling 1,132 beds, would not participate in the program. This would leave 57 hospitals, having 2,544 beds, to support an engineering service program.

A proposed budget for the optimal engineering services program in section 5.4 is presented in Appendix C. Considering that the first three year start-up period was subsidized by a grant, the annual sustaining cost would be $138,890.00. If this annual cost was supported by the 57 hospitals not having engineering service programs, the cost per bed would be $54.59. If existing state health department services were expanded to include the 3 BMET's and additional engineers listed in the proposed budget of Appendix C, hospital financial responsibility for the budget would be reduced. Hospitals would have to support the $20,000.00 operating cost and the $6,510.00 cost for replacement of equipment. This

consideration would reduce the cost per bed of the 57 smaller hospitals to $10.42. It should be noted that this would require expansion of present health department services. This proposed engineering services program would provide engineering services in South Dakota. Grant funding of the three year start-up period would be most desirable. Continuation of the program could possibly be supported by state, federal and/or hospital funds. Based on findings in this study, it is questionable as to whether the hospitals alone could sustain a $54.59 charge per bed. This emphasizes the hospitals' need for additional assistance financially.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary

This study was conducted to determine the feasibility of a predetermined engineering services program in South Dakota. The study surveyed engineering services needs of South Dakota hospitals with the intent of determining their basic needs in the engineering services area. Based on these findings, the hospitals' acceptance of a privately operated engineering services company was found to be poor. An alternate plan was proposed based on this and other specific limitations unique to South Dakota.

6.2 Conclusions

This study determined that South Dakota hospitals are in need of many engineering services, but hospitals question the cost of those services, even though they may be required to have such services available in the near future. Hospitals would like to have their own personnel educated and trained to perform as many of the basic engineering services as possible. Findings indicated that a faster, more economical and efficient source of corrective maintenance is needed, as well as a qualified source of competent engineering guidance and assistance. South Dakota's problems

are somewhat unique, having a majority of small hospitals below national average hospital capacities, and being sparsely located in an almost entirely rural area. Because of these features and a lack of financial resources in general, the problems of South Dakota hospitals are somewhat unique. Financial assistance is needed to provide and initiate optimal services.

It can be said that the efficiency of health care delivery is somewhat dependent upon the availability of engineering services and competent engineering guidance for the hospital. If South Dakota hospitals are to obtain optimal and efficient delivery of health care, they must have economical, comprehensive, and competent engineering services available to them.

The first step and most feasible solution to many of these unique problems seems to be the utilization of existing resources within the state of South Dakota. Efforts should be directed at furthering the technical capabilities of South Dakota's resources, and building upon them. Present Health Department services can be utilized and expanded. Universities can provide a source of educational resources and technical guidance. A second step in solving these problems is the organization of an engineering services center with mobile capabilities to provide the services South Dakota hospitals are economically and

efficiently unable to provide. The completion of an engineering services center and the non-profit organization of its services would provide South Dakota hospitals with the economic, flexible, and comprehensive engineering services presently needed.

6.3 Recommendations

This thesis is only an initial survey of the existing needs for engineering services in South Dakota. A more detailed survey is necessary to determine the extent and satisfaction with present services available. An economic feasibility study could be of great assistance in determining each hospital's acceptance of the optimal plan. A study of available educational and training resources in the state and organization of a program utilizing those resources could be of great benefit to the proposed plan. The application of computers to preventative maintenance schedules and inventory records would be another area requiring study. The state-wide use of a computer for bookkeeping and medical records could also be a very challenging project. Along similar lines, a study could consider the possibilities of a group administrative organization for mass purchasing, consulting, and maintenance services.

All areas of further study can be of great benefit to South Dakota and other hospitals. Even though South Dakota has somewhat unique problems, similar states have similar

problems. Solutions to South Dakota's problems can benefit many. Although this thesis has presented an optimal plan and budget, the author feels that the costs will be questioned and termed unnecessary by some hospitals. But, the author contends that South Dakota hospitals will soon have to have many of these services available, to provide health care delivery equivalent to national levels, and that all efforts should be made immediately to provide adequate engineering services to South Dakota hospitals.

SELECTED REFERENCES

1. Griffin, Noyce L., "Electronics for Hospital Patient Care." Public Health Service Publication. Washington, D.C.: Superintendent of Documents, Reprinted July 1969, No. 930-D-25, p. ix.

2. Dodson, Burt, Jr., Carolinas Hospital Engineering Support Services. Charlotte: Carolinas Hospital and Health Services, Incorporated, June, 1973.

3. Link, David M., and Larry R. Pilot, FDA's Medical Device Program. Washington, D.C.: DHEW Publication, No. (FDA) 73-4002, Reprinted from May 1972.

4. Woods, Michael, "Computer Tests Planned for Hospital Equipment," The Blade, Toledo, Ohio: August 12, 1973.

5. Egeberg, Roger O., "Engineers and the Medical Crisis," Proceedings of the IEEE, Vol. 57, November 1969, pp. 1807-8.

6. Eberhard, Michael J., and Malcolm Ridgeway, "Development of a Biomedical Engineering Shared Service in Southern California," Hospital Forum, February 1974.

7. Callum, Merrill and Alan R. Shapiro, "A New Defibrillator Analyzer," Medical Electronics and Data, July/August 1973.

8. Electrical Safety in the Hospital and How to Get It. Stoughton, Massachusetts: Hospital Safety Testing Labs, Incorporated, 1974.

9. National Electrical Code. Boston: National Fire Prevention Association, McGraw-Hill Book Company, Inc. 1972.

10. Occupational Safety and Health Administration, Code of Federal Regulations. Washington, D.C.: Superintendent of Documents, Revised July, 1973, No. 29.

11. 1973 National Fire Prevention Association Publications and Visual Aids. Boston: National Fire Prevention Association, 1973.

12. Bugliarello, George, and others, "A Study of Health Care in Western Pennsylvania," Proceedings of the IEEE, Vol. 57, November 1969, pp. 1853-69.

13. Commercial Atlas and Marketing Guide, Rand McNally and Company, 1973, pp. 484-5.

14. Hogan, Edward Patrick, Lee A. Opheim, and Scott Zieske, Atlas of South Dakota, Dubuque: Kendall/Hunt Publishing Company, 1970, pp. 105, 131.

15. 1973 American Hospital Association Guide to the Health Care Field, Chicago: American Hospital Association, 1973, pp. 193-194.

16. South Dakota Hospitals Licensed by South Dakota State Department of Health. Pierre: Health Facilities Program, Division of Community Services, South Dakota State Department of Health, January 25, 1974.

17. Doherty, Neville, "Rurality, Poverty, and Health: Medical Problems in Rural Areas," Agriculture Economic Report. Washington, D.C.: Superintendent of Documents, February 1970, No. 1972.

18. South Dakota Highway Map. Pierre: South Dakota Department of Highways, 1972.

19. Johns, Richard J., "What is Blunting the Impact of Engineering on Hospitals?" Proceedings of the IEEE, Vol. 57, November 1969, pp. 1823-27.

20. Kane, Irwin M., Nyack Shared Biomedical Instrumentation Engineering Plan, Nyack, New York: Director of Engineering Services, Nyack Hospital, 1974.

21. Aronow, Saul, and Raymond Peter Zambuto, Pilot Study for a Medical Engineering Shared Services. Burlington: Massachusetts Hospital Association, 1973.

22. Pearce, J. A., and T. S. Hargest, "Development of the Model Program for Carolina Hospital Engineering Support Services," Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Vol. 15, 1973, p. 349.

23. Woods, Michael, "Service Center Planned for Medical Electronics," The Blade, Toledo, Ohio: April 12, 1972.

24. Northwestern Ohio Clinical Engineering Center. Health Planning Association News Letter. Toledo: Health Planning Association of Northwest Ohio, March 1973, p. 3.

25. Senda, Warren, "Project to Serve Biomed-Electronics Gear in Hospitals," Honolulu Advertiser, January 1, 1974.

26. Advertising literature from Instrutek, Inc., 15 Lincoln Park Center, Annapolis, Maryland, 1974.

27. Gilder, Jules H., "Consumerism and the Makers of Medical Electronics Collide," Electronic Design 5, March 1, 1973.

28. College Placement Council Salary Survey. Bethlehem, Pennsylvania: The College Placement Council, Incorporated, January 1974.

NON-REFERENCED MATERIAL

Bierman, Leland, and Mark J. Powers, Ambulance Services in Northwest South Dakota. Brookings: South Dakota State University Economics Department, Agriculture Experiment Station, Bulletin 569, April 1970.

Callum, Merrill, "How Safe is Your Hospital?" Medical Electronics and Data, May/June 1970.

Electrical Environment and Safety for the Modern Hospital, Washington University. St. Louis, Missouri: School of Continuing Education, Washington University, June 9, 1973.

Jarzembski, W. B., "Safety in the Hospital - An Overview," Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Vol. 15, 1973, p. 240.

Knox, A. E. Hertzler, Clinical Engineering Newsletter. Arlington, Virginia, The Association for the Advancement of Medical Instrumentation: December 1973.

Patient Safety, Application Note AN718. Waltham, Massachusetts: Hewlett-Packard Company, 1971.

Rock, K. C., "A Modern Hospital's Approach to Patient Electrical Safety," Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Vol. 15, 1973, p. 434.

Sander, D. E., W. Engle, and J. Robertson, Electrical Safety and Maintenance in Health Care Facilities. Brookings: South Dakota State University, March 1974.

Shackleton, Dennis, and others, "The Ellerbe Report on Electrical Hazards Within Medical Facilities," Ellerbe Architects, Bloomington, Minnesota: January 18, 1972.

Steadman, J. W., "Training Hospital Staff in Biomedical Safety," Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Vol. 15, 1973, p. 432.

The Distribution of Physicians, Hospitals, and Hospital Beds in the United States, 1966. Chicago: American Medical Association, 1967.

Truxal, John G., "Technology and Health Services," Proceedings of the IEEE, Vol. 57, November 1969, pp. 1802-6.

Using Electrically-Operated Equipment Safely with the Monitored Cardiac Patient. Waltham, Massachusetts: Hewlett-Packard Company, March 1970.

Wear, J. O., "Hospital Patient Safety," Proceedings of the 26th Annual Conference on Engineering in Medicine and Biology, Vol. 15, 1973, p. 431.

APPENDIX A

SOUTH DAKOTA HOSPITALS LICENSED BY THE SOUTH DAKOTA STATE DEPARTMENT OF HEALTH

JANUARY 25, 1974

ADDRESS	NAME OF HOSPITAL	NO. BEDS
Aberdeen	Dakota Midland	130
Aberdeen	St. Luke's Hospital	160
Armour	Douglas County Memorial	21
Belle Fourche	John Burns Memorial	40
Bowdle	Bowdle Hospital	20
Britton	Marshall County Memorial	34
Brookings	Brookings Hospital	61
Burke	Community Memorial	25
Canton	Canton-Inwood Memorial	34
Chamberlain	Community Bailey	44
Clear Lake	Deuel County Memorial	17
Custer	Custer Community	16
Deadwood	St. Joseph's Hospital	48
Dell Rapids	Dell Rapids Community	29
DeSmet	DeSmet Memorial	19
Estelline	Estelline Community	16
Eureka	Eureka Community	35
Faulkton	Faulk County Memorial	36
Flandreau	Flandreau Municipal	32
Freeman	Freeman Community	30
Gettysburg	Gettysburg Memorial	35
Gregory	Gregory Community	25

ADDRESS	NAME OF HOSPITAL	NO. BEDS
Hot Springs	Southern Hills General	49
Hoven	Holy Infant	31
Huron	St. John's Regional Medical Center	149
Ipswich	Ipswich Community	19
Kadoka	Memorial Hospital	15
Lake Preston	Kingsbury County Memorial	14
Lead	Homestake Hospital	30
Lemmon	Five Counties	30
Madison	Madison Community	68
Martin	Bennett County Community	20
McLaughlin	McLaughlin Hospital District	27
Milbank	St. Bernard's Providence	35
Miller	Hand County Memorial	32
Mitchell	Methodist Hospital	90
Mitchell	St. Joseph's Hospital	136
Mobridge	Mobridge Community	50
Parkston	St. Benedict Hospital	30
Philip	Hans P. Peterson Memorial	20
Pierre	St. Mary's Hospital	138
Platte	Platte Community Memorial	27
Rapid City	Rapid City Regional Hospital	267
Rapid City	Rapid City Rehabilitation	52
Redfield	Community Memorial	46

ADDRESS	NAME OF HOSPITAL	NO. BEDS
Scotland	Landmann-Jungman Memorial	25
Sioux Falls	Crippled Children's	64
Sioux Falls	McKennan Hospital	301
Sioux Falls	Sioux Valley Hospital	357
Sisseton	Coteau Des Prairies	29
Spearfish	Lookout Memorial	20
Sturgis	Community Memorial	39
Tyndall	St. Michael's Hospital	25
Vermillion	Dakota Hospital	47
Viborg	Pioneer Memorial	35
Wagner	Wagner Community Hospital	17
Watertown	Memorial Hospital	94
Watertown	St. Ann's Hospital	70
Webster	Day County	39
Wessington Springs	Jerauld County Memorial	37
Winner	Baptist Hospital	40
Yankton	Sacred Heart	155

APPENDIX B

A QUESTIONNAIRE USED TO SURVEY SOUTH DAKOTA HOSPITALS AND THEIR NEEDS FOR ENGINEERING SERVICES

Dear Administrator,

The Bioengineering Program of the Electrical Engineering Department of South Dakota State University is conducting a study to determine the feasibility of an engineering services program for South Dakota hospitals. We feel that you as an administrator have the best understanding of your own hospital's needs; we are therefore asking your assistance in filling out the attached questionnaire and returning it to us by February 8, 1974. An addressed-stamped envelope is enclosed for your convenience. I would like to take this opportunity to thank you in advance for your cooperation.

Please keep in mind that this survey is a State University co ducted study and is not backed by any private concerns. Please be objective and answer all questions. All South Dakota hospitals will fill out this same questionnaire and your reply will be kept in complete confidence. Completed results of this study will be available to you as a participant and to the Health Facilities Program of the State Health Department, who is aware of this study. Thank you again for your assistance.

Sincerely,

Duane E. Sander

Dr. Duane E. Sander
BioEngineering Program
Electrical Engineering Department
South Dakota State University
Brookings, SD 57006

Introduction:

The results of this survey will serve as a valuable input in determining the feasibility of an Engineering Service program for the rural hospital. This program would include the following four areas:

1. Electrical safety analysis - of the hospital environment and all electric and electronic instruments; detection and prevention of electrical hazards to patients and personnel.

2. Routine and corrective service for medical electronic instruments used in clinical, therapeutic, and routine health care areas.

3. Engineering consulting and technical services.

4. Supply of medical electronic instrumentation.
   a. Leasing, b. Sale, c. Rentals

Your cooperation in completing this survey questionnaire will be greatly appreciated. A free synopsis of the results of this survey will be available to any listing their address below.

Name_____

Hospital_____

City_____

South Dakota Zip Code_____

PART I. ELECTRICAL SAFETY AND ELECTRONIC MAINTENANCE

1. Does your hospital perform routine:

	Yes	No
a) Visual Electrical Safety Checks	( )	( )
b) Ground Integrity Checks	( )	( )
c) Outlet Polarity Checks	( )	( )
d) Current Leakage Checks on Electronic Instruments	( )	( )

2. Which hospital department is responsible for those checks and what is the title of the person in charge?

Department_____

Title_____

3. What is the number of personnel involved in (may be some overlapping)

_____ a) Electrical Maintenance

_____ b) Medical Electronic instrument repair and maintenance

_____ c) TV, and other electronic repair and maintenance

_____ d) Electrical safety checking

4. Would you like to make additional and more extensive electric safety checks on your medical electronic instruments, power outlets, and grounding systems in your hospital? Yes ( ) No ( )

5. How do you solve service problems on your present medical electronic instruments. (Please indicate the relative percentages each solution contributes).

_____ a) Have the hospital's electrical technician repair it.

_____ b) Discard the faulty instrument permanently.

_____ c) Contact the company you have a maintenance contract with.

_____ d) Contact the manufacturer and ask them to send out a service representative.

_____ e) Contact a local or nearby electronic technician, TV repairman, etc.

6. Would you like to have this same engineering services program provide efficiency tests and routine maintenance on your heating and cooling system? ____yes ____no

7. Number in order of importance the areas your hospital needs an engineering service program for: (1 is most important)

_____ Electrical Safety Analysis

_____ Electronic Instrument Maintenance

_____ Heating System Maintenance

_____ Cooling System Maintenance

This survey is a feasibility study for an Engineering Services Program, designed to indicate the acceptability of such a service to the smaller hospital in South Dakota. Present trends indicate that routine electrical safety analysis of the hospital and its biomedical equipment may some day be a prerequisite to hospital accreditation.

Consider that this Engineering Service Program is available to you;

1. One complete annual electrical safety analysis of all patient and staff areas to include these tests and checks:
   a. Current leakage measurement of any electrical equipment
   b. Ground continuity and integrity checks
   c. Outlet polarity and condition
   d. Visual inspection of other electrical apparatus

2. Engineering consulting and technical services for electric - biomedical equipment.

3. Telephone service line available 24 hrs/day.

4. Maintenance of medical electronic instrumentation via service contracts or on a time and materials basis at $15.00/hour plus parts cost.

To get a better idea of this service acceptability in South Dakota, we would like to have you perform the indicated calculations below for your hospital. Fill in the appropriate number and multiply this by the estimated unit cost to obtain the approximate cost for your facility. Total the columns and use this cost when answering the remaining questions:

Unit Cost	Number	Total
$10.00 per bed	(x) #general patient beds (#____)	$_____.00
$75.00 per room	(x) #operating and recovery rooms (#____)	$_____.00
$45.00 per room	(x) #delivery and emergency rooms (#____)	$_____.00
$20.00 per bed	(x) #ICU and CCU beds (#____)	$_____.00
$75.00 for physical therapy area		$_____.00
$45.00 for Laundry area		$_____.00
$75.00 for Kitchen area		$_____.00
$75.00 for Laboratory		$_____.00
TOTAL YEARLY		$_____.00

8. Would you find this yearly cost a reasonable rate for the described services if you were required to make the listed safety checks and tests of your hospital and instruments? ____YES ____NO

9. Would you find this cost a reasonable rate for the described services if you were not required to make the listed safety checks of your hospital and instruments? ____YES ____NO

10. Could this program reduce your administrative costs?
____YES ____NO ____DON'T KNOW

11. Does the cost seem attractive to you presently?
____YES ____NO ____DON'T KNOW

12. Do you think you could obtain the same services more economically in some other way? ____YES ____NO ____DON'T KNOW

PART II. INSTRUMENTATION

1. Please fill in the chart below according to the following instructions:

a) Indicate with a check ( ) whether you lease, own, or rent the listed biomedical equipment.

b) Indicate with an (X) your preferred means of obtaining that equipment, if different.

c) Indicate in colum A the number of these instruments in your hospital.

d) Indicate in colum B the number of these instruments in need of repair, replacement, or updating.

e) Indicate in colum C the number of these instruments you are adding or replacing in the next year.

f) Indicate in colum D the average number of service problems per year per instrument.

g) Indicate in colum E the average down time per month of that instrument.

h) Indicate in colum F the average expected lifetime of the instrument.

Leave any unapplicable rows blank.

Please make any additions to the list that are missing.

	LEASE	OWN	RENT	BIOMEDICAL EQUIPMENT	A	B	C	D	E	F
1				AC OR DC DEFIBRILLATOR						
2				ELECTROCARDIOGRAPH						
3				CARDIAC MONITORS						
4				CARDIAC PACEMAKER (EXTERNAL)						
5				FETAL MONITOR						
6				ELECTRONIC THERMOMETER						
7				ELECTROSURGICAL & ELECTROCAUTERY UNITS						
8				HYPO- OR HYPERTHERMIA UNITS						
9				DIATHERMY UNITS						
10				ELECTROTHERAPY UNITS						
11				VACUUM INSTRUMENTS						
12				ELECTRIC BEDS						
13				CONDUCTIVE FLOOR TESTER						
14				CONDUCTIVE SHOE TESTER						
15				STRIPCHART RECORDERS						
16				ELECTRIC ENCEPHALOGRAPH						
17				HOMOGENIZER						
18				RESPIRATOR						
19				INHALATION THERAPY UNIT						
20				PULMONARY FUNCTION EQUIPMENT						
21				O_2, CO_2, or N_2 ANALYZERS						
22				PLETHYSMOGRAPH						
23				SPIROGRAPH						
24				THYROID FUNCTION EQUIPMENT						
25				HEART CONDUCTION SYSTEM LOCATOR						
26				HEART-LUNG MACHINE						
27				RADIOISOTOPE EQUIPMENT						
28				RADIATION SCANNERS & COUNTERS						
29				ELECTROENCEPHALOGRAPH						
				LABORATORY EQUIPMENT						
30				CENTRIFUGE						
31				CELL & COLONY COUNTERS						
32				BLOOD VOLUME ANALYZER						
33				BLOOD & URINE AUTOANALYZER						
34				AMINO ACID ANALYZER						
35				ELECTROPHORATOR						
36				GRINDER						
37				MICROSCOPE						
38				SPECTROMETER						
39				FLUOROMETER						
40				ULTRASONIC CLEANERS						
41				CHROMATOGRAPH						
42				MICROTOMES						

2. Please check your preferred means of obtaining medical electronic instruments in the following value categories.

Value	Lease	Own	Rent
0 to $100	( )	( )	( )
$100 to $500	( )	( )	( )
$500 to $1000	( )	( )	( )
$1000 to $2500	( )	( )	( )
$2500 to $5000	( )	( )	( )
$5000 to $7500	( )	( )	( )
$7500 to $10,000	( )	( )	( )
$10,000 to $25,000	( )	( )	( )
$25,000 to $37,500	( )	( )	( )
$37,500 to $50,000	( )	( )	( )

3. Please list medical electronic instruments that you presently have a lease on, service contract on, or both and indicate such.

	Instrument	Manufacturer	Years Leased	Service Contract	Lease
1.	_____	_____	_____	( )	( )
2.	_____	_____	_____	( )	( )
3.	_____	_____	_____	( )	( )
4.	_____	_____	_____	( )	( )
5.	_____	_____	_____	( )	( )
6.	_____	_____	_____	( )	( )
7.	_____	_____	_____	( )	( )
8.	_____	_____	_____	( )	( )
9.	_____	_____	_____	( )	( )
10.	_____	_____	_____	( )	( )
11.	_____	_____	_____	( )	( )
12.	_____	_____	_____	( )	( )

4. Do you think an Engineering Services program should provide for the supply of medical electronic instrumentation? ____YES ____NO

5. Would you feel it advantageous to have all the engineering serviced needed by the hospital handled by one organization? ____YES ____NO

Comments: _____

_____

_____

_____

_____

THANK YOU FOR YOUR ASSISTANCE.

Please fold and insert this questionnaire into the enclosed stamped addressed envelope and drop in the mail. Thank you. Please return by February 8, 1974.

APPENDIX C

A BUDGET

FOR A COMPLETE ENGINEERING

SERVICES PROGRAM FOR

SOUTH DAKOTA HOSPITALS

PHASE I - YEAR 1		
3 Instructors at $100.00 each per day for 3 days 2 times per year at 4 locations	$ 7,200.00	
3000 miles of travel at 10¢ per mile	300.00	
Food and lodging at $40.00 per day for 3 persons for 24 days	2,880.00	
Publications and materials	2,000.00	
Part-time administrative director	8,000.00	
TOTAL - PHASE I		$ 20,380.00
PHASE II - YEAR 2		
Director	$18,000.00	
2 Engineers	32,000.00	
3 BMET's for last half of year 2, based on $14,000 annual salary	21,000.00	
Secretary	8,000.00	
Operating Expenses	10,000.00	
Continuation of Phase I	12,380.00	
TOTAL - PHASE II		$101,380.00

PHASE III		
1 Director	$18,000.00	
2 Engineers	32,000.00	
3 BMET's	42,000.00	
2 Mobile Vehicles	20,000.00	
Test Equipment (2 sets)	20,000.00	
Secretary	8,000.00	
Operating Expenses	20,000.00	
Continuation of Phase I	12,380.00	
TOTAL - PHASE III		$172,380.00
TOTAL 3 YEAR COST		$293,140.00
SUSTAINING COST PER YEAR (includes phase III less Vehicles and equipment, plus replacement costs of equipment at $6,510.00)		$128,890.00
Annual Cost Per Bed (3,676 Beds)	$ 37.78	
Annual Cost Per Bed (2,544 Beds)	$ 54.59	